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Resource Notes-Fall/Winter 1987-88

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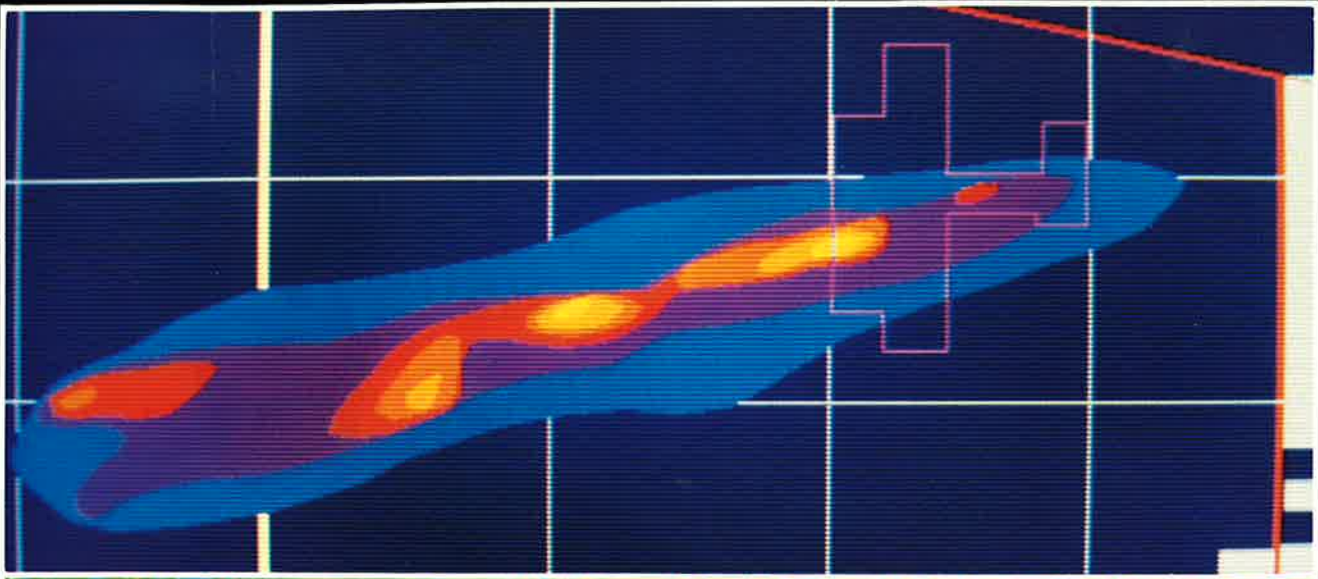

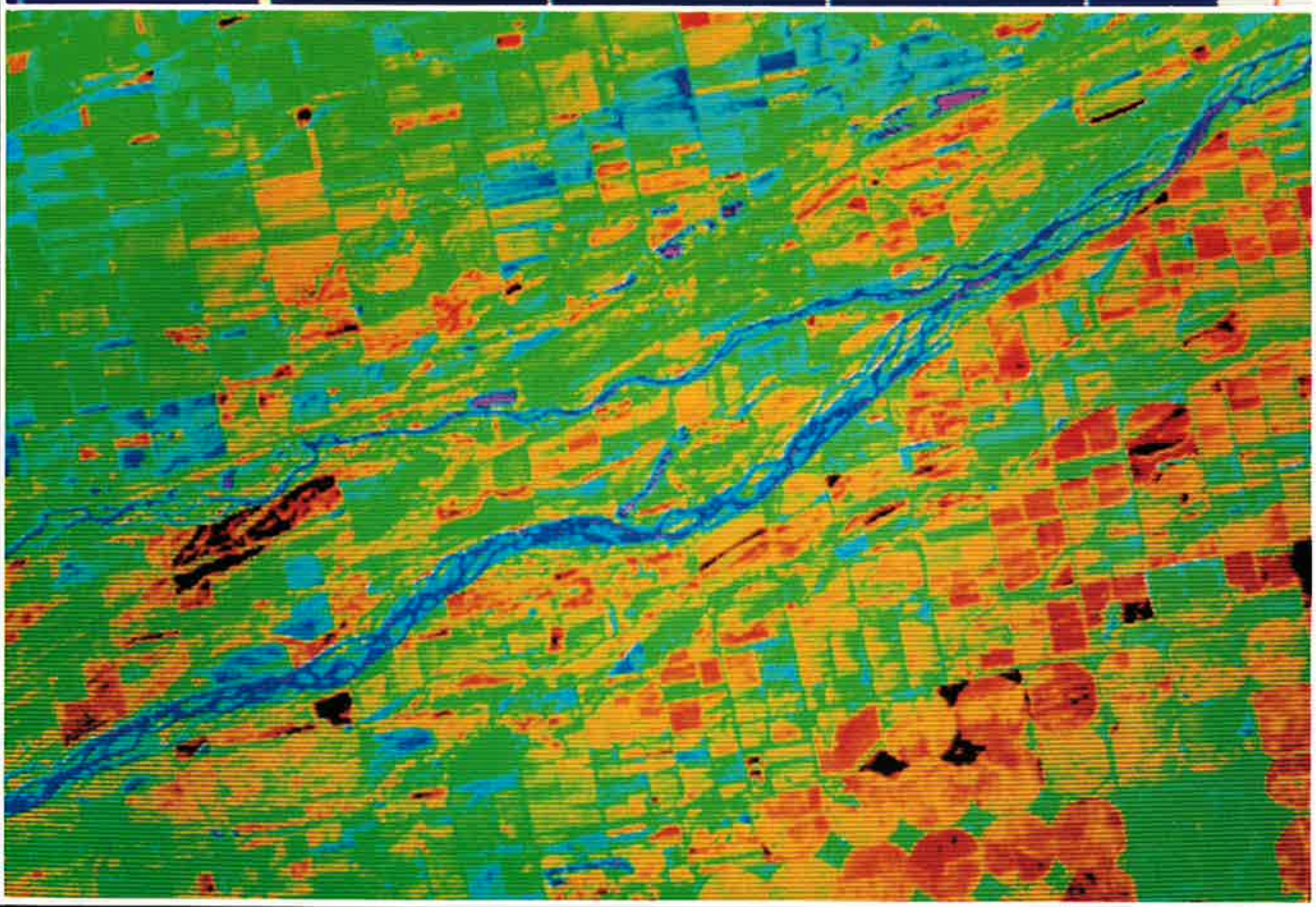

The quarterly of the Conservation and Survey Division

A Focus on Groundwater Quality:

Future of State's Economy Tied to Groundwater-Quality Research

The future prosperity of Nebraska is inescapably linked to sustaining the integrity of the state's water resources. This is true whether the future is tied to agriculture or whether economic diversification brings industry of other types. Adequate supplies of good quality water will be needed for drinking water for humans and livestock, as well as for irrigation of crops and for industrial water supplies. Since groundwater in Nebraska is the source of 84 percent of public drinking water supplies, 72 percent of irrigation supplies and 85 percent of self-supplied industrial use, any contamination that makes it unsuitable for its intended uses is of significant concern. However, the mechanisms of contaminant movement and of contaminant interaction with groundwater are still not well understood. Much early research in water pollution dealt with surface water.

Only in recent years has the emphasis shifted to groundwater, which in many respects is a much more complex problem. Since water is a very powerful solvent and since groundwater comes in contact with many substances that can dissolve, groundwater often contains a great variety of both naturally occurring chemicals and those introduced by humans.

The University of Nebraska is responsible for conducting research that provides information on management practices and policies regarding water quality. Experience has already proven that it is far more practical to prevent pollution of groundwater than it is to correct it afterward. Only by a thorough understanding of the mechanisms and principles of groundwater pollution will it be possible to implement the policies and management practices that will prevent such contamination. These policies also will require a thorough understanding of the economics of control and prevention, as well as the psychological and institutional aspects of pollution control. However, existing examples of contaminated groundwater dictate that we also must develop effective, economical means for cleaning up current problem situations.

Past and current water-quality research efforts at the University of Nebraska have produced much useful information, but the effort is still minimal compared with the magnitude of the problem and its importance to the state's future. Rational policy measures demand a good understanding of the impact of pollution on humans, plants, animals and even microbes. For example, this information is essential to developing new approaches to the development of safe pesticides, effective means of their application, innovative alternatives to the use of toxicants and methods of decontaminating problem areas.

Despite much concern, relatively little evidence exists on the possible health effects of agriculturally related chemicals in groundwater. Prohibiting chemical use by agriculture would directly decrease product quality and availability, as well as increase price. Without adequate research to assess agricultural and urban impacts on water quality, rational policy decisions simply cannot be made without risk of unnecessary impacts on farm and consumer economics.

Research efforts will never be adequate to address all the problems and obtain all the answers. We must concentrate our research on the problems most critical to Nebraska's future and most representative of the state's prevailing conditions. Then we must do everything possible to obtain the resources needed to adequately address the problems and recommend solutions before negative impacts are allowed to prevail. Scientists and engineers in the UNL Institute of Agriculture and Natural Resources are well qualified to conduct much of the needed research and are already involved to a significant degree. With sufficient resources and faculty, it is not too late to use our research capabilities to stop the problem before it reaches dangerous and burdensome proportions.

Dale Vanderholm, Interim Dean
Agricultural Research Division, IANR

Resource Notes

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Resource Notes is a quarterly publication of the Conservation and Survey Division of the Institute of Agriculture and Natural Resources, 113 Nebraska Hall, University of Nebraska-Lincoln, 68588-0517. It is distributed free to all interested in earth science. To receive it, write to the address above. The Conservation and Survey Division is the agency designated by statute to investigate and interpret the geologically related natural resources of the state, to make available to the public the results of these investigations and to assist in the development and conservation of those resources. The division provides information and educational programs to all people without regard to race, color, national origin, sex or handicap.

On the front cover: *(top) Areal distribution of U.S. Army Research Department Explosive (RDX) plume in groundwater as of November-December 1984, an example of point-source contamination. Eastern end of plume is under the Capital Heights area (outlined in pink) near Grand Island (white area to the right). Blue is a concentration of .1-10 parts per billion RDX; violet: 10-40 ppb; red: 40-50 ppb; orange: 50-70 ppb; yellow-orange: 70-100 ppb; yellow: >100 ppb. White lines are section roads; bold white line is eastern boundary of Cornhusker Army Ammunition Plant.* Graphics by Donn Rodekohr, CALMIT, CSD. *(bottom) A false-color composite of the Central Platte region near Wood River. Reflectance values are lowest in the violet range and grade progressively higher through blue, green, yellow, orange, red and black. Runoff from nearby cropped fields that enters the Platte River can contain pesticides and nitrates, making the river a potential line source of groundwater contamination.* Graphics by Lloyd Queen, CALMIT, CSD.

On the back cover: *A DRASTIC map showing groundwater vulnerability to contamination near Stanton. DRASTIC is a methodology for determining this vulnerability. Colors represent low to high vulnerability; gray is the lowest, grading through tan, blue, dark green, green, yellow, orange and red, which is the highest. CSD is helping the Nebraska Department of Environmental Control use the DRASTIC technology to determine special groundwater protection areas in compliance with the Nebraska Groundwater Management and Protection Act. Of particular concern in passing the special protection area legislation was increasing contamination by nitrates and other nonpoint-source pollutants.* Graphics by John W. Jones, CALMIT, CSD.

CALMIT's 'DRASTIC' Transfer:

Mapping Aquifer Vulnerability a Cooperative Effort for CSD, DEC

by Kate Pritchard
Public Information Intern, NDEC

The Center for Advanced Land Management Information Technologies (CALMIT) is transferring technology that will make a "DRASTIC" difference to the Nebraska Department of Environmental Control (NDEC) in designating Special Groundwater Protection Areas. CALMIT is a program of the Conservation and Survey Division, Institute of Agriculture and Natural Resources, at the University of Nebraska-Lincoln. The DRASTIC system compiles hydrogeological and soils information into one map that shows the relative vulnerability of an aquifer to pollution in a specific region.

DRASTIC stands for the seven mappable factors:
—D = DEPTH to Water
—R = RECHARGE
—A = AQUIFER Media
—S = SOIL Media
—T = TOPOGRAPHY
—I = IMPACT of the Vadose (Unsaturated) Zone
—C = Hydraulic CONDUCTIVITY

Developed in 1985 by the National Water Well Association and the U.S. Environmental Protection Agency, DRASTIC was first applied in a joint project between CALMIT and the Nebraska Department of Health to evaluate the potential for groundwater pollution at Cozad, Neb.

The NDEC became interested in the technology to determine special protection areas in compliance with the Nebraska Groundwater Management and Protection Act of 1986.

The NDEC and CALMIT entered a 50-site contract carried out from February to December, 1987. CALMIT's responsibility was to develop the technology, assuring geometric accuracy, and to produce the graphics. It is NDEC's place to apply that information.

The 1986 special protection area legislation was passed because of increasing groundwater contamination by nitrates and other nonpoint-source pollutants, said NDEC geologist Paul Brookner. NDEC is evaluating contaminated areas and areas where contamination is possible, looking to prevent those possibilities, Brookner said.

Before a special protection area can be designated, a detailed study must be conducted. DRASTIC allows a standardized approach for determining groundwater vulnerability.

"DRASTIC is one of four criteria being used to determine the priority of definite areas around the state in order to use our limited funds where they are most needed first," Brookner said. The other criteria are area users, or the area's population; the existing quality of the groundwater in the area; and the availability of a second potable water source.

Each DRASTIC parameter is given a rating of 1 to 10: 10 being the most vulnerable and 1 the least vulnerable. The rating scale is weighted relative to the seven factors present in a specific area, Brookner said.

Gene Murray, a water scientist formerly with CSD, wrote a report on the Cozad project and described DRASTIC as follows:

—Depth to water is one of the most important factors in determining pollution potential. 0-5 feet deep rates a 10; 100 feet deep or more is a 1.

—Recharge: The primary source of groundwater is precipitation that infiltrates through the earth's surface.

—Net recharge indicates the amount of water that reaches the water table. The greater the recharge, the greater the pollution potential because chemicals in the soil are flushed down with the water. 10+ inches of recharge is a 10 rating; 0-2 inches is rated 1.

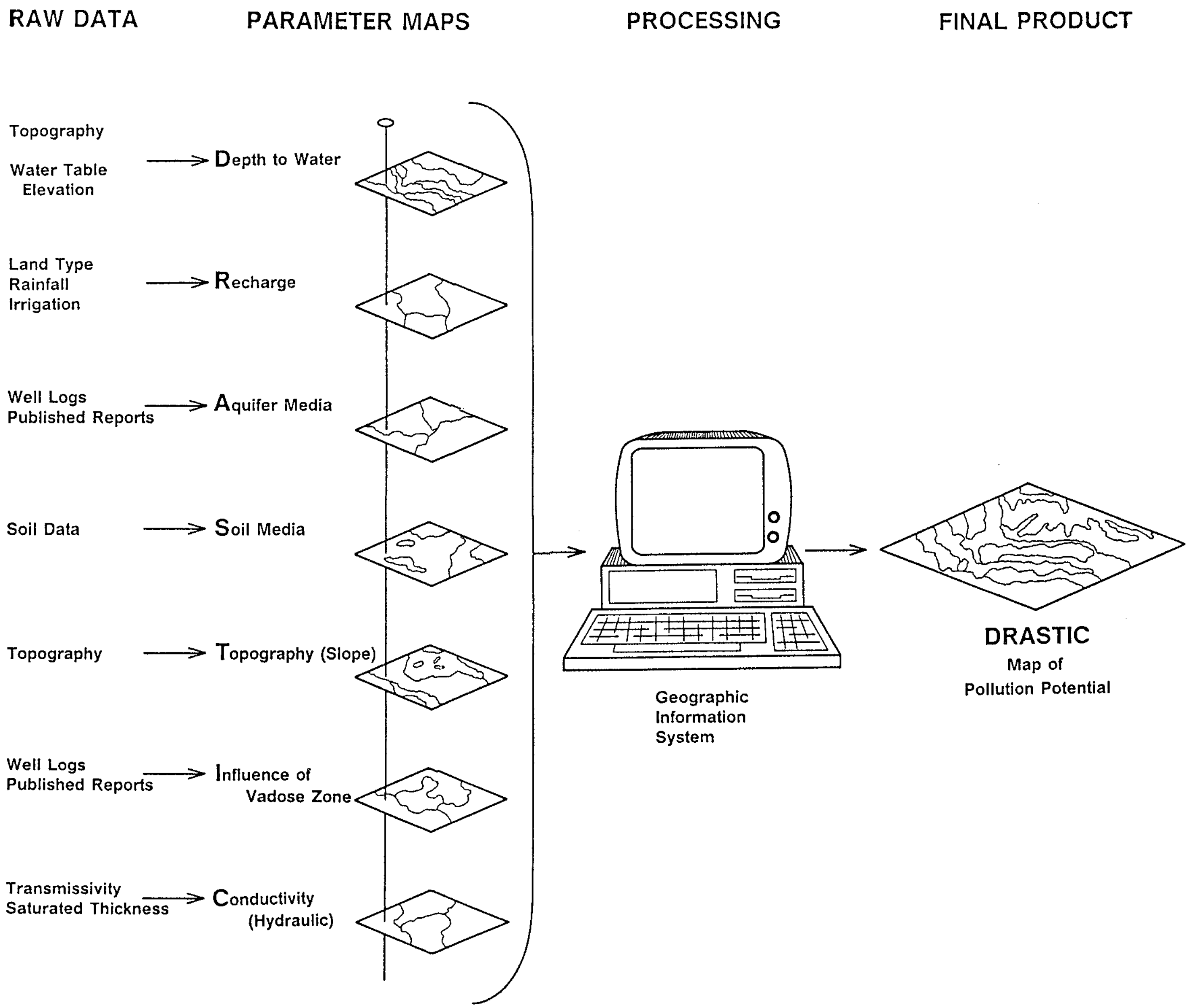
—Aquifer media is the stratum of rock or sediment that contains supplies of water. If the media is highly permeable, a contaminant is not detained and enters the groundwater. Karst limestone rates from 9 to 10; sand and gravel rates 6 to 9; and massive shale rates 1 to 3.

"DRASTIC is one of four criteria being used to determine the priority of definite areas around the state in order to use our limited funds where they are most needed first."
—Brookner

—Soil media is the upper weathered zone of the earth, which averages 3 feet or less, in which significant biological activity occurs. The soil zone affects the movement of non-point-source pollutants in particular. Thin or absent soil media is rated 10; clay loam is a 3; and nonshrinking clay is rated 1.

—Topography or the slope of the land surface affects how quickly a contaminant penetrates the soil. A high percentage slope forces a contaminant to move across the surface while a flatter surface lets a contaminant be drawn down faster. A 0-2 percent slope is rated 10; and 18+ percent slope is rated 1.

—Impact of the vadose zone media refers to the unsaturated area above the water table and below the soil where water doesn't completely fill the void spaces in the medium. Biodegradation, neutralization, mechanical filtration, chemical reaction, volatilization and dispersion all occur to some extent within the vadose zone. The contaminant's residence time there controls how much a contaminant is neutralized before reaching the water table. A karst-limestone vadose zone rates 8 to 10; sand and gravel rate 4 to 6; and clay is rated 1 or 2.



DRASTIC parameters and raw data incorporated

—Conductivity refers to the capacity of a porous material to transmit water under a hydraulic gradient; the rate that groundwater flows also controls the rate the contaminant will be moved from the point it entered the aquifer. Transmissivity was estimated by the gallons per day that move through a square foot: 2,000+ gallons moving through a square foot in a day rates 10; 1-100 gallons moving through a square foot in a day is rated 1.

After all seven factors are mapped, each is assigned a DRASTIC rating, which is multiplied by their DRASTIC weights, explained Jeremy Dillon, CALMIT research assistant. The DRASTIC weights are designed to show the importance of the DRASTIC parameters relative to each other.

All data is entered into a computer; maps are entered via a digitized pad in a manner similar to tracing on a light table. The computer combines the data on a single map that shows aquifer vulnerability to contamination by colors, the warmest colors indicating the highest vulnerability and the cool colors the lowest vulnerability.

New publications from the Conservation and Survey Division

Publications:

—Geology of Selected Sites Near the Republican River in Franklin County, Nebraska: R. K. Pabian (1987)—$3.50 (EC-7)

—Hydrogeology of Garfield and Wheeler Counties, Nebraska: D. R. Lawton and R. A. Hiergesell (1988)—in press

Maps:

—Mineral Resource Map of Nebraska, 1987: R. R. Burchett; color print (1:1,000,000)—$3.00

Creating plans exacting but positive experience

Groundwater-Management Plans Point to Research Needs for NRDs

The groundwater management plans developed by Nebraska's natural resources districts (NRDs) have yielded a variety of promising projects for researchers in groundwater geology and related disciplines, said Jerry Ayers, one of a number of Conservation and Survey Division researchers who reviewed the plans. And though the NRD directors and staff "grumbled a bit" about the rigors of preparing the plans, those involved said learning about the complexities of their resource was "nothing but positive," according to Gene Murray, a former CSD hydrogeologist who consulted with the NRDs during the preparation process.

These two hydrogeologists and seven other CSD scientists have reviewed the management plans, as well as Bob Kuzelka, a CSD water-resources planner who, along with Murray, developed a handbook that the NRDs could use to guide them through this rather exacting task. As set down by the Nebraska Groundwater Management and Protection Act, each NRD in the state was charged with preparing a groundwater-management plan. Made mandatory by the state legislature in 1984, the plans were to be submitted to the director of the Nebraska Department of Water Resources (DWR) by Jan. 1, 1986.

Since most of the NRD managers knew the needs of their constituencies but were less familiar with the specific technical data on their groundwater resource, the division approached the Nebraska Association of Resource Districts in the summer of 1984 about how best to get this information to those who needed it. The handbooks were the result.

"It was a big educational program," Kuzelka explained. "We've had a staff person in touch with every NRD as a result of this," he added. Not only was it an opportunity for the division's Norfolk, North Platte and Scottsbluff field offices to provide service needed outstate, he said, but the division's Lincoln staff put on specialized workshops for five or six NRDs and attended board meetings of about a third of them.

"It was the most complete contact we've had with them since their early days," Kuzelka added.

The law required the NRDs to first set down the technical groundwater setting with the known data, then decide how long they wanted their resource to last and how they proposed to meet that goal. Accordingly, the handbooks provided an overview of the resource's technical parameters, offered a checklist for the plan's preparation based on the legal requirements and provided a reference list of organizations and publications that could provide more data. Of the 23 initially submitted plans, 16 were approved. One NRD with an extensive groundwater control area did not have to submit a plan. As of October 1987, three NRDs had chosen to resubmit their plans, and they have been approved by DWR.

Since most of the NRDs had been cooperating with CSD and the U.S. Geological Survey on their water-level monitoring program, most did a reasonably good job of detailing the issues related to water quantity, Kuzelka said. Water-quality concerns were less well understood, Ayers said. In addition to pointing to the need for more basic data regarding the proper management of fertilizers and pesticides, the management plans have yielded some potential studies regarding secondary aquifers in various regions. These include further studies on the possibilities of secondary aquifers in northeast Nebraska and in the Papio and Nemaha NRDs, as well as studies related to irrigation in the Central Platte, Middle Republican and Middle Niobrara NRDs.

"There's no way agriculture can change overnight. It has to be a phasing-in, phasing-out type of process. Demonstration studies have shown that fertilizer amounts can be kept way down by closer monitoring (of soil fertility). It's the same with pesticides."

—Ayers

After reviewing the plans, Ayers mentioned that he saw good possibilities for interdisciplinary studies on the fate of pesticides and fertilizers in the environment. Such studies could also include hydrochemists, biochemists and agricultural engineers.

"There's no way agriculture can change overnight. It has to be a phasing-in, phasing-out type of process," he said, speaking of the need for moderation in application of these inputs. "Demonstration studies have shown that fertilizer amounts can be kept way down by closer monitoring (of soil fertility). It's the same with pesticides."

He also noted that there hadn't been a lot of concern demonstrated by municipalities beyond ensuring an adequate drinking water supply. An area where urban areas could excel, he said, would be in monitoring potential contamination sites such as landfills, railroad yards, loading docks, gas storage tanks and grain elevators, anywhere there is any type of chemical use or disposal.

"It's an interesting grass-roots planning approach," Kuzelka said. "What I hope to do is summarize the plans and the types of goals because I think the legislature sort of carried them this far and then left them. And there's really no idea about whether they should implement (their plans), or how; or if they don't, what happens, or if they do, what happens."

Since they were submitted and approved, many NRDs have implemented some aspects of their plans. For instance, in a well-publicized case, the Central Platte NRD has adopted groundwater-quantity and -quality management areas based on its plan. Other NRDs have increased the scope of their groundwater-quantity monitoring programs. Many have begun groundwater-quality monitoring programs. In addition, groundwater and aquifer characteristics that were identified in the management plans as requiring more research have been the subjects of recently initiated studies, Kuzelka added.

The data assembled in the plans also has been helpful to NRDs as they were called upon last year to begin regulating chemigation and now as they may have to plan for special groundwater protection areas if nonpoint pollution has occurred or may begin showing up.

"The bottom line of this early planning effort," Kuzelka said, "is a common awareness in all 24 of the state's NRDs of their groundwater and their responsibility in its management."

Burlington-Northern study ends in 1989

Future of Water-Quality Studies in Doubt Without More Funds

by Charles Flowerday
Editor, CSD

Many important issues related to the quality of Nebraska's groundwater could go unexplored if the Institute of Agriculture and Natural Resources receives no more funding for follow-up studies after the Burlington-Northern Foundation water-quality research project is completed, according to Roger Gold, coordinator for environmental programs, IANR, University of Nebraska-Lincoln.

The IANR has been seeking funding for further studies related to the effects of chemigation—applying fertilizers and pesticides through irrigation water—on groundwater quality. However, the only interest expressed so far has been by the U.S. Environmental Protection Agency (EPA) and Geological Survey (USGS) in funding research on cleaning up after contamination has occurred, said Gold, who coordinates the $1 million project.

"We should be looking at prevention of the problem, rather than cleanup, but I guess that people just flat-out recognize, either consciously or subconsciously, that there are going to be problems. Therefore, they're looking for remedial action."

—Gold

Besides research into cleanup after a backflow event, areas examined in the study include two other major topics and a few sub-projects. The other major areas are the evaluation of chemical-injection and backflow-prevention equipment and an assessment of the interrelationships of various pesticides, fertilizers and tillage practices. The latter topic involves sub-projects studying nitrogen cycling and movement in the soil; the fate and movement of herbicides under various tillage practices; the fate and effectiveness of an insecticide applied through irrigation water under different tillage systems; and the influence of tillage, irrigation and application variables on the degradation and leaching of three pesticides.

"There have been several attempts to find funding to support on-going research. We have approached the Burlington-Northern Foundation, asking if they would be interested in an extension (of the present grant)," Gold said. But it is too early for a response from the foundation yet, he added.

In addition to the EPA and USGS, administrators of the BN project have contacted the Cooperative Extension Service, which is interested but does not expect any increase in federal funding that would allow for support of such studies. The regional office of the water-quality section of the EPA has said it is interested in funding research into cleanup after backflow or back-siphoning of chemicals. Roy Spalding, a hydrochemist with the UNL Conservation and Survey Division, is currently examining this problem. But investing only in research on cleaning up contamination, Gold said, is a poor scenario.

"We should be looking at prevention of the problem, rather than cleanup, but I guess that people just flat-out recognize, either consciously or subconsciously, that there are going to be problems," he added. "Therefore, they're looking for remedial action."

Money from the Clean Water Act, recently amended to include provisions governing nonpoint pollution—such as that from fertilizers and pesticides—could provide support for further studies, he added. Such funding would come from the state Department of Environmental Control. But because the act has not been funded by Congress, only passed, this money can't be counted on yet.

Once the "hard data" from the project comes in, Gold said, the prospects for more funding may improve. The 5-year research effort will conclude in 1989.

The project has been recognized by the Nebraska Groundwater Foundation, receiving the 1987 award for business achievement, and has received considerable media attention. "I think it's well-perceived, nationally and internationally. We've had people from different areas of the country come to find out about it. It's a good, solid concept. It's just that it takes lots of money to run a good program," he said.

The project is getting a lot of attention because it's addressing some questions that are not being explored anywhere else in the region. Because it's very expensive to fund this kind of comprehensive research, many people are waiting for the results of the present project before they invest in similar studies.

"I know that's particularly true in surrounding states because we get regular contacts from Kansas and Iowa wanting to know where we are. They have legislation on chemigation, and they want to know what they should write in their regulations," he said. "It really is a model program and has the potential to be well-cited and recognized in the scientific literature."

If and when money is available, future studies should look into "fail-safe" safety equipment, such as the check valves designed to prevent a backflow of chemicals, he added. Another problem requiring more investigation is the environmental fate of various pesticides. This takes much longer than five years to determine, Gold explained. The final results of the BN project will barely scratch the surface of our understanding of the interaction between pesticides and the soil, he said.

More investigation of integrated pest management also is needed, so that producers become less dependent on chemicals that could cause environmental problems, Gold added.

"But whenever you eliminate an input into agriculture, you're affecting the income of some other sector of the community," he said.

Research into resistant varieties, computerized decision models and better ways to monitor crop damage and weather patterns will also help reduce reliance on agricultural chemicals. Biological controls being developed through the new biotechnology offer promise as well, he said. A number of bacteria and viruses—known as specific pathogens—can be used to control pests with no known effect on humans.

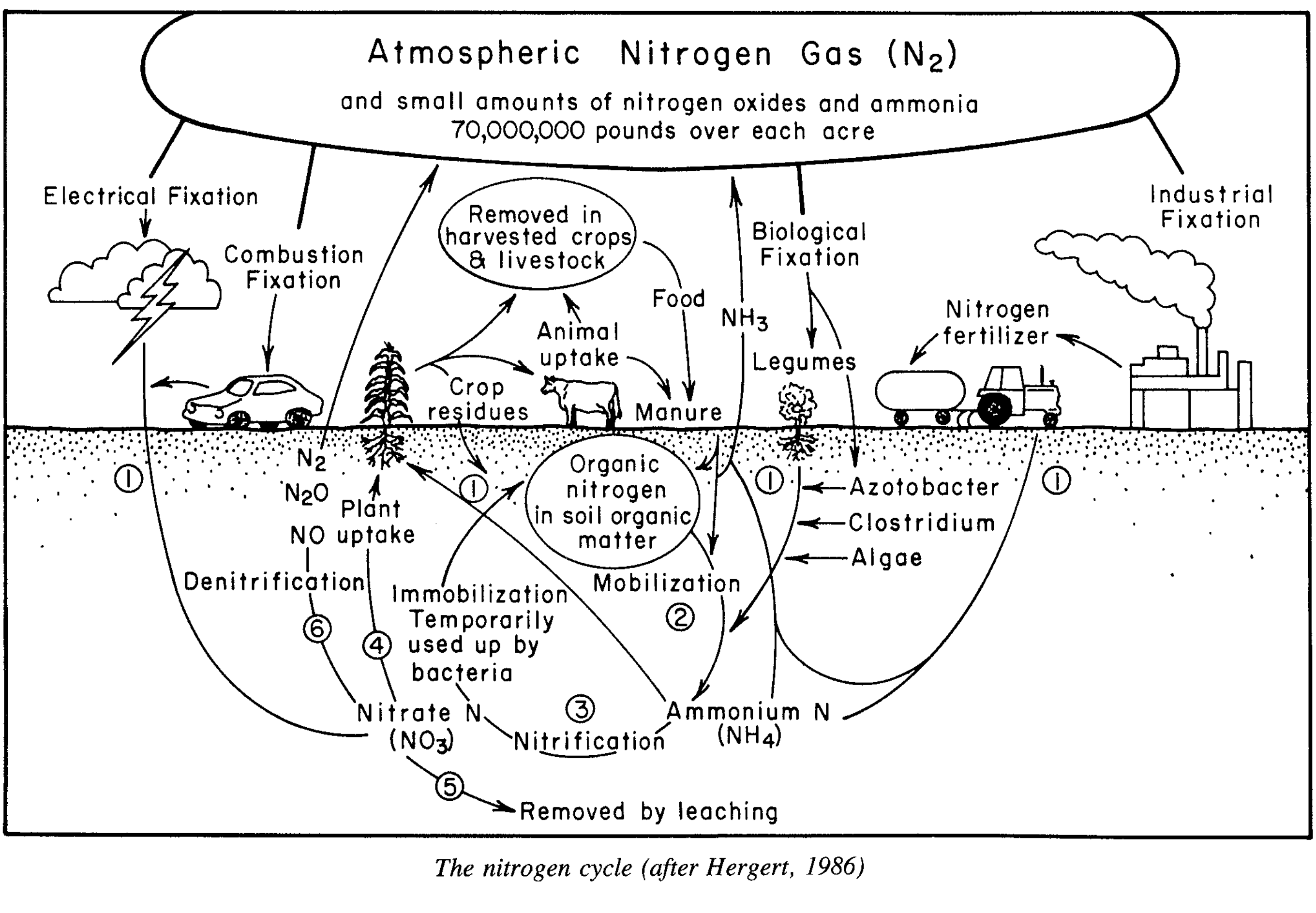
"But again, who is going to pay for that research? Certainly it will not be the traditional pesticide companies," Gold said. "There's so much more to be done, but the economic climate of the state has been such that there's little room for growth, to try to move away from the traditional. If we try to move away from the traditional, we are sometimes criticized for not being responsive to our clientele."

One approach taken by other agricultural states, such as Iowa, has been to impose a levy on agricultural chemicals sold in the state, which supports research and extension activities related to those chemicals. While he is not advocating this for Nebraska, Gold said, it is an approach that should be evaluated. In addition, he said, recognition should be given to organizations like the Nebraska Fertilizer and Agricultural Chemical Institute and the Nebraska Association of Independent Crop Consultants for their efforts to ensure that these chemicals are used safely and effectively, he added.

Regarding the difficulties of effecting change, Gold asked hypothetically: what would be the consequence of cutting by half the amount of pesticides sold and used in the state? It would mean the loss of $100 million a year from the state's economy, he explained.

"The (negative) consequences of that are probably greater than to continue the present cash flow through the system. The point is that through integrated pest management, even at the level at which we do it today, we know that significant

1) Nitrogen in plant and animal residues and nitrogen derived from the atmosphere through electrical, combustion, biological and industrial fixation processes are added to the soil. 2) Nitrogen in the residues is mobilized as ammonium by soil organisms as an end-product of residue decomposition. Plant roots adsorb a portion of the ammonium. 3) Much of the ammonium is converted to nitrate by nitrifying bacteria in a process called nitrification. 4) Nitrate is taken up by plant roots and (along with the ammonium adsorbed) is used to produce the protein in crops that are eaten by humans or fed to livestock. 5) Some nitrate is lost to groundwater or drainage systems as a result of downward movement through the soil in percolating water. 6) Some nitrate is converted by denitrifying bacteria into molecular nitrogen and nitrogen oxides that escape into the atmosphere, completing the cycle.



The nitrogen cycle (after Hergert, 1986) reductions could be made. But there's so much pressure to maximize return on investment that there may be a tendency to over-use these chemical resources as insurance applications,'' he said. Such ''insurance'' is sold as a guarantee that the producer will have high yields. Such marketing of fertilizers and pesticides may have even more effect as marginal lands are taken out of production, putting more pressure on growers to use chemicals on the remaining land.

''We're very concerned about reports that certain lending institutions will not give production loans unless you agree to use certain levels of agricultural chemicals. That's exactly the wrong direction. We should be talking about reducing inputs into production, while still maximizing net return,'' he said.

However, any discussion of ''organic farming'' may be missing the point also, he said, because it may be impractical in many situations. The return to pay the equipment and land loans frequently isn't enough to cover the risks inherent in the large investments common in farming.

''Besides there's just flat-out not enough manure to go around. And the cost of hauling manure may be greater than using more traditional fertilizers. The total cost of production should be examined closely before making decisions regarding inputs of chemicals.

But considering the protection of water quality, he explained, means asking what is the true cost of fertilizers and pesticides. The cost of buying and applying agricultural chemicals does not represent the total cost of the use of the product, especially when groundwater cleanup costs are included. But it's hard to consider the hidden costs associated with the use of any chemical when one is most concerned with making it through the production year, Gold said.

Asked if he favors the continued use of agricultural chemicals in Nebraska, Gold said that in his opinion the use of fertilizers and pesticides ensures the quality and quantity of food and fiber in the United States.

''However, we certainly can do a better job of addressing the questions regarding the environmental consequences of these important agricultural chemicals. The challenge is to conduct the research, get the results and deliver the information through the extension system soon enough that we can be pro-active in heading off problems before they occur. The cost of only reacting to them as they occur is just too great,'' he explained.

Nitrates May Be a Producer's Boon and a Baby's Bane

Nitrates: mysterious, misunderstood and sometimes maligned.

Rising levels of nitrates in Nebraska's groundwater have raised concerns about groundwater quality, concerns that have been taken all the way to the state legislature.

Sometimes nitrate levels in water demand action; at other times, they probably do not, according to Richard Wiese, extension soils specialist at the University of Nebraska-Lincoln.

In 1987, new regulations for certain areas of the Central Platte Natural Resources District—which includes all or parts of Dawson, Buffalo, Hall, Merrick and Polk counties—have banned fall application of nitrogen fertilizer on sandy soils. This area contains an average level of nitrate-nitrogen in groundwater between 12.6 and 20 parts per million. The Safe Drinking Water Act of 1973 established 10 parts per million nitrate-nitrogen in drinking water as the maximum contaminant level allowed by the U.S. Environmental Protection Agency.

In certain areas, groundwater with a high level of nitrate is available for irrigated crops. Each part per million of nitrate-nitrogen is equal to 2.7 pounds of available nitrate in each acre-foot of water. That's the good news. The bad news is that drinking water for pregnant women and infants 6 months or less should contain no more nitrates than 10 parts per million. If it does, Nebraska law says that bottled water must be provided because of the risk of methemoglobinemia, the ''blue-baby syndrome,'' which results when infants consume water high in nitrates.

The state Department of Health monitors new water sources for 12 months after installing municipal or municipally owned public water-supply systems. And due to nitrates in excess of 10 parts per million in drinking water, 26 towns in Nebraska are under administrative order of the health department to supply bottled water.

''It's not the nitrate that's the problem,'' Wiese said. He explained that nitrogen is essential in our environment. Forms of nitrogen are converted to the nitrate ion throughout the ecological system. However, the problem arises when too much soluble nitrate-nitrogen accumulates in plants and groundwater.

Within the nitrogen cycle, the element can occur in any of these forms:

—NO_3-N: nitrogen in the nitrate form,
—N: nitrogen,
—NO_3: nitrate,
—NO_2: nitrite,
—NO_2-N: nitrite-nitrogen.

The process occurs as follows: nitrate seeks oxygen when changed from one of these forms to another. Nitrates continually attempt to return to their relatively stable NO_3 state. In the human body, nitrites must receive oxygen from the blood stream in order to be returned to their original nitrate state. In plants, nitrites get their oxygen from plant fluids and return to nitrates.

When any of the processes are interrupted, for example, with the lack of oxygen, nitrite takes over. Then problems can begin. Furthermore, nitrate is relatively nontoxic; it is easily ingested and excreted when all the body's systems are working correctly.

However, with the addition of bacteria, such as in contaminated wells or in mammals, trouble begins.

Wiese explained that some microorganisms need oxygen just as humans need oxygen. Where do these organisms get it? From nitrates in water—thus, we have the toxic form as nitrites. On the other hand, if the well is bacteria-free, nitrates can't be converted to the toxic nitrite.

''It's essential to have sanitary wells. No bacteria means no nitrites,'' Wiese said. — Pat Larsen

Keeping Up with Groundwater Quality, Quantity Keeps These People Going

In the last issue of Resource Notes, we began a series featuring faculty and staff of the Conservation and Survey Division who are officed elsewhere besides the first floor of Nebraska Hall, the main part of the division's physical plant. In keeping with an issue devoted to groundwater, we would like to introduce a few of these people whose work keeps them intimately involved with some aspect of surveying and investigating the condition of the state's groundwater:

—Roy Spalding and Mary Exner Spalding, hydrochemist and chemist, respectively, whose labs and offices are in the Walter Scott Engineering Center, just south of Nebraska Hall. The Spaldings' groundwater-quality investigations are presented in the following article.

—Bob Hansen, CSD basic-data supervisor, who works out of the Georesources Building but spends a great deal of his time driving around the state taking measurements and maintaining equipment for the state-federal groundwater-level measurement program. An article on Hansen's work appears on page 24.

Groundwater-Quality Research Spans the State

Roy Spalding and Mary (Exner) Spalding, CSD hydrochemist and chemist, respectively, have done a wide variety of investigations into the quality of Nebraska's groundwater since coming to the division in 1974. They are leaders in the state and are nationally recognized researchers in this kind of work. Most of these studies have been regarding nonpoint-source contamination, some regarding point- and line-source contamination. In addition to local investigations, they have pursued regional water-quality studies. In addition, in 1978, CSD published the Groundwater Quality Atlas of Nebraska, co-authored by Roy Spalding and Dick Engberg of the U.S. Geological Survey, which is available from the division. The following are brief descriptions of selected ongoing or completed studies over the past 5 years in which the Spaldings have been principal investigators.

In addition, the following people have assisted these studies as investigators, technicians or graduate students:

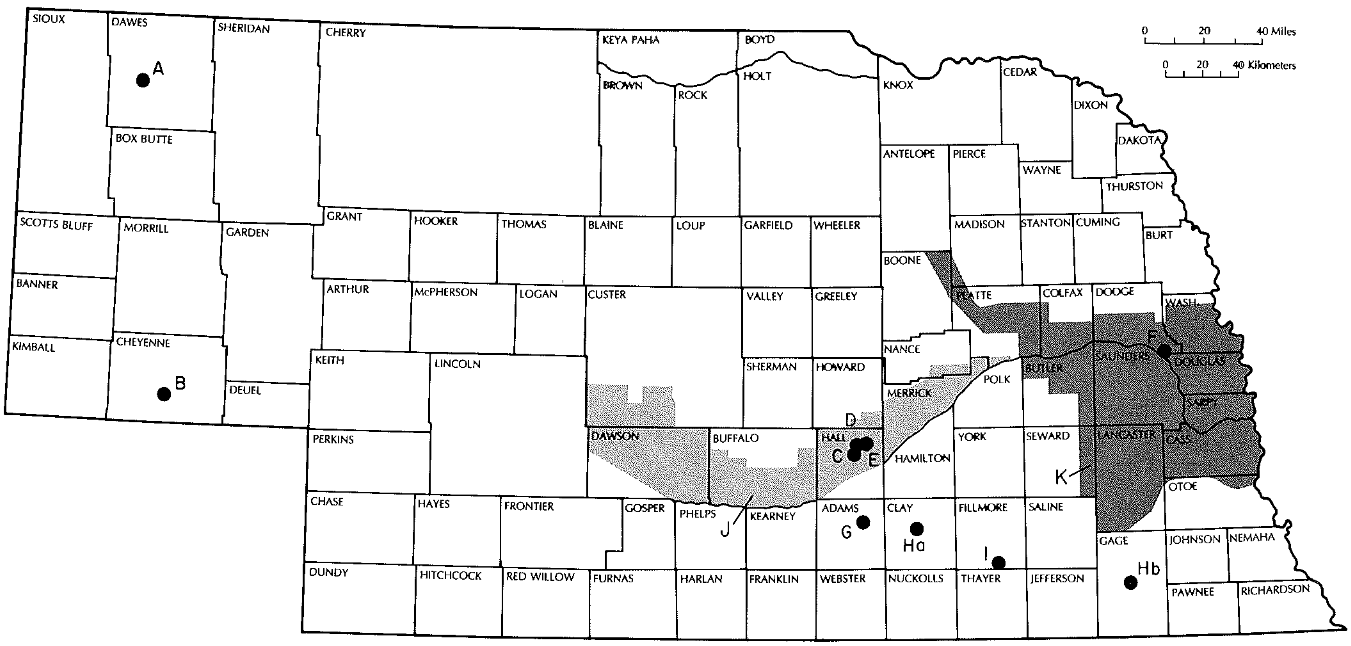
Bart Brown; Anthony Bryda; Mark Burbach; Ralph Cady; Gene Debus; Douglas Druliner; Alex Fischer; John Fulton; Ingrid Gless-Verstraeten; Mitchell Herbel; Lisa Kitchen; Stephen Myers; Jack Parrott; Elizabeth Rowan; Daniel Snow; Arthur Struempler; Cindy Stuefer-Powell; Michelle Unger; Glen Wehtije; Lowell Whiteside; Carol Yamane.

Funding for these studies was provided by: Central Platte, Little Blue, Lower Big Blue, Lower Platte North, Lower Platte South, Papio and South Platte NRDs; U.S. Environmental Protection Agency; Argonne National Laboratory; Burlington-Northern Foundation; Nebraska Department of Environmental Control; Metropolitan Utilities District; City of Lincoln; and the City of Fremont.

(A) Monitoring potential groundwater contamination in a proposed uranium-mining area - vicinity of Chadron

Approximately 100 groundwater samples in the vicinity of the proposed Crow Butte in-situ-leach uranium-mining site in northwestern Nebraska were analyzed to determine the baseline chemical constituents. Head values were examined to determine local and regional groundwater flow and the configuration of the water table. Samples were collected from wells with completion depths in Tertiary sediments of the Arikaree and White River Groups. Within the latter group, samples were obtained from the Brule and Chadron Formations, of which the basal Chadron sandstone represents the aquifer in which the uranium mineralization occurs.

Analyzing these waters for differences in their chemical character should allow for detection of excursions from the ore-bearing unit. The singular geochemical nature of the basal Chadron groundwater in the mineralized area makes possible the use of several tracers for detecting potential leakage to the groundwater above. The chemistry of the aquitard not only is unique, but it also is quite homogeneous, allowing for easy detection of post-mining contaminants during the restoration phase. Uranium and uranium isotopes are potentially good tracers for such excursions.



Water-quality studies begun or completed by Roy F. Spalding and Mary Exner Spalding during the last 5 years

(B) Nitrate-nitrogen profiles documenting land-use practice effects on groundwater in and around Sidney

Residents of the Sidney area obtain their present water supply from eight municipal and numerous private wells penetrating the Brule Aquifer. These wells have been experiencing increases in nitrate concentrations over a 20-year period. Sidney and the South Platte Natural Resources District would like the source(s) of contamination identified so as to control the contaminant and not surpass the maximum contaminant level set by the U.S. Environmental Protection Agency for nitrate-nitrogen in their water supply.

This investigation is to determine the major source of nitrate-nitrogen contamination upgradient and immediately west of the city. Continuous cores will be obtained, and nitrate-loading effects beneath different land uses will be observed. Those land-use practices are agronomic, livestock feeding and care of fertilized lawns.

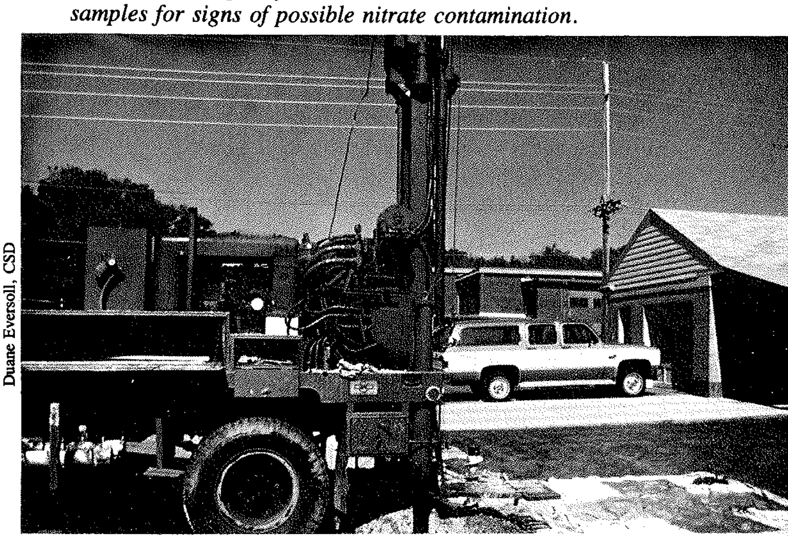
(C) Geochemistry of groundwater denitrification - vicinity of Alda

Denitrification is a mechanism by which toxic nitrate is converted by reduction to nontoxic nitrous oxide and nitrogen gas. Data indicate that this process occurs in frontal areas near Alda. Denitrification was evidenced by enrichment of the heavier isotope of nitrogen in nitrate and by lowered nitrate values with depth. Highest nitrous oxide levels occurred in the shallow nitrate-laden groundwater. This may indicate that denitrification is occurring in the shallow groundwater; however, the nitrous oxide may also originate during ammonia nitrification reactions. More research demonstrating the direction of nitrous oxide flux in the unsaturated zone is needed.

(D) Distribution of Research Department Explosive (RDX) in groundwater of Hall County, Nebraska - vicinity of Capital Heights near Grand Island

High levels (>35 parts per billion) of the U.S. Army Research Department Explosive (RDX) in local groundwater prompted the army to provide bottled water for the several hundred people in the Capital Heights area of Grand Island until the problem could be remedied by extending city water mains to the area. The potential health hazards associated with RDX and its degradation products caused the army to establish a maximum permissible concentration for safe drinking water at 35 micrograms per liter RDX. After their manufacture at the Cornhusker ordnance plant, the contaminants were leached from wash in 56 cesspools, burning areas and leaching pits, which received waste. Groundwater samples from a number of monitoring, irrigation and domestic wells were collected to assess the areal

CSD groundwater-quality investigations in the Sidney area have included drilling in feedlots and on lawns in town to examine samples for signs of possible nitrate contamination.



Duane Eversoll, CSD

extent of 2,4,6-trinitrotoluene (2,4,6-TNT); 2,4-dinitrotoluene (2,4-DNT); 2,6-dinitrotoluene (2,6-DNT); 1,3,5-trinitrobenzene (1,3,5-TNB); nitrobenzene (NB); and hexahydro-1,3,5-trinitro-1,3,5-triazine, also referred to as cyclotrimethylene trinitramine (RDX).

The observed RDX plume was about 4 miles long in December 1984 and conformed to the classic cigar shape. It was about 1 mile wide along the western end of the plume and tapered to about 0.2 mile near its eastern end.

The vertical distribution of RDX indicates that the plume is slowly migrating deeper in the Pleistocene sand and gravel aquifer. The plume sinks as a result of natural recharge along the flow path at a rate greater than a foot a year. Thus, the highest RDX concentrations (>100 parts per billion) beneath Capital Heights are at 40-50 feet.

Although more TNT than RDX was produced and although more time (43 years) had elapsed since its initial manufacture, the areal distribution of 2,4,6-TNT is less expansive than that observed for RDX. Physical and chemical processes such as photodegradation, sorption, and biodegradation limited the amount of TNT in the groundwater and its transport distribution. Compared with the RDX, the TNT plume was much smaller.

(E,F) Excursion and cleanup from chemigation backflow

A recent development of center-pivot irrigation has been the application of fertilizers and pesticides to crops by direct injection into an operating system—chemigation. Environmental problems such as chemical drift, residue-contaminated runoff, residue-contaminated groundwater from leaching and siphoning of chemicals directly to the groundwater are areas of concern. Of these concerns, the greatest environmental hazard occurs when toxic chemicals are back-siphoned into the source water.

Although chemicals can be applied through drip, gravity-flow and sprinkler systems, sprinkler systems are by far the most widely used. In Nebraska about 40 percent of more than 27,000 center-pivot irrigation systems are used to chemigate. While new laws mandate check valves on all systems used to chemigate, approximately 10 percent of these systems still are not equipped. Some check valves were found to leak and need new seals. Even when timely inspections occur, it is generally conceded that there will be at least a 1 percent failure rate.

(E) Site I - vicinity of Capital Heights near Grand Island

In 1985 a monitoring network was set up to specifically address the back-siphoning problem. Twenty-five multilevel samplers and three wells were installed in the primary aquifer within 25 feet of an irrigation well. Sodium bromide (a harmless tracer) was injected into the irrigation well on four occasions. The tracer was used to simulate the movement of a contaminant that had been back-siphoned. Despite numerous changes in the monitoring network, a plume of bromide never was detected. While it was obvious that the project design was a failure, the reason was unknown at first. The only anomaly was a half-inch decline in the water level at the irrigation well. To verify the design failure, two more wells were installed in the second aquifer beneath the silty clay layer. Head data indicated that, before pumping, the water level in the secondary aquifer was 0.83 feet lower than in the primary aquifer. It had been assumed that the silty clay retarded movement between the primary and secondary aquifers. However, these data indicated that strong downward flow occurs where windows exist between the aquifers. The response between one of the monitoring wells and the irrigation well during a pump test indicated a good hydraulic connection existed between them.

A final tracer test verified that transport from the irrigation well to the secondary aquifer was occurring. It also revealed that pumping in the secondary aquifer strongly distorted the radial flow towards the pumping well. This implied that in non-pumping conditions the local vertical flow far exceeds horizontal flow and also explained the previous experimental failures.

The experiment demonstrates the need for strong compliance in check-valve installation and maintenance. In the case in point and according to the local drillers, over-drilling is common in irrigation-well installation and probably has resulted in many windows permitting downward penetration of chemicals. Back-siphoning in these circumstances would be partially irreversible and the well's hydraulics would need to be known prior to any remedial action.

(F) Site II - vicinity of Fremont

A second site has been developed at the Fremont well field about 3 miles southeast of Fremont. As in the previous investigation, a series of multilevel sampling devices were installed in an arc downgradient of an irrigation well.

After spiking the irrigation well with sodium bromide in May 1987, significant sodium bromide concentrations above background levels were observed at depths of 30-65 feet in four multilevel samplers southeast of the irrigation well. The peak concentration was 51 percent (2.55 parts per million) of the original spike concentration.

The irrigation well was spiked again on June 18; sampling occurred at more frequent intervals. The spike was observed in eight multilevel samplers southeast of the irrigation well. Peak concentration was 38 percent (3.8 parts per million) of the original spike and occurred at the same depth and in the same multilevel sampler as in the May spiking. The spike diluted and dispersed rapidly as it moved out from the irrigation well. The breakthrough curves and peak concentrations in the samplers varied dramatically. The maximum concentrations occurred at 30 feet in one sampler after 66 hours, but not until 198 hours at the 27-foot level. The groundwater flow rate varies significantly on the micro level.

In July, the irrigation well was pumped at a rate of 600 gallons per minute for 3 hours to withdraw the sodium bromide. Sixteen depths with the highest detected sodium bromide concentrations were sampled every 3 minutes. None of the samples had bromide concentrations above background levels, indicating complete dilution of the spike with the groundwater.

Later in July, the irrigation well was pumped for 48 hours to simulate a pumping irrigation well and was spiked with 100 parts per million sodium bromide—10 times higher than the previous spiking—immediately after turning off the irrigation well. The results were similar to those obtained in June.

In August, the irrigation well was pumped at a rate of 600 gallons per minute for 2 hours and 50 minutes to withdraw the sodium bromide. A significant sodium bromide concentration occurred at various depths throughout the pumping, indicating that although the return concentration had been greatly diluted, it would still require a considerable pumping period to remove the entire sodium bromide.

The excursion and cleanup from chemigation backflow project continues to demonstrate the extremely complex nature of remedial action involving chemigation back-siphoning. Experiments re-enacting back-siphoning and defining the problems involved with back-siphoning are continuing.

Duane Eversoll, CSD

Roy Spalding (directly to the left of the van) explains the chemigation-backflow investigation to a group of CSD support staff last summer in the Fremont well field. Small bundles of white tubes in the foreground are multilevel samplers used to monitor levels of simulated contamination.

(G) Volatile Organic Compounds (VOCs) in groundwater influenced by large-scale withdrawals - Hastings

Ten wells were installed to monitor water-table elevations and volatile organic compounds (VOCs) in groundwater underlying Hastings, Nebraska. Trichloroethylene (TCE) was the most frequently detected VOC and had the highest concentration (1,750 micrograms per liter) in these monitoring wells. Perchloroethylene (PCE), 1,1-dichloroethylene (1,1-DCE), 1,2-dichloroethane (1,2-DCA), and 1,1,1-trichloroethane (TCA) also occurred in one or more of the monitoring wells.

The vertical and areal VOC distribution in both the contaminated monitoring wells and the city's contaminated municipal wells are largely related to withdrawal caused by heavily pumped municipal and industrial wells nearby. A computer model was used to demonstrate the impact historic site changes in high-capacity well withdrawal have on the local water-table configuration. Two sites of suspected VOC sources were designated for further study.

(H) Nitrate movement in fine-textured unsaturated sediments:
a) NU South Central Research and Extension Center near Clay Center
b) vicinity of Beatrice

More than 2,000 feet of unsaturated core have been collected, extracted and analyzed for nitrate-nitrogen concentrations. Nitrate profiles have been investigated beneath pristine fields, non-irrigated farmland, irrigated fertilized cropland, feedlots and urban lawns. Sampling the unsaturated (vadose) zone is a valuable tool in water-quality research because the results are relatively easy to interpret, samples can be taken where drilling probably would not be allowed, from a lawn or feedlot, for example, and it allows for prediction of future problem areas.

Investigated sites were located in southeastern, south-central and southwestern Nebraska. All sites were in areas of predominantly fine-textured soils. Fertility plots, which received from 0 to 400 pounds of nitrogen fertilizer per acre, showed a high degree of association between vadose nitrate and applied nitrogen. These data are unquestionable evidence that there is significant nitrate leaching below the crop rooting zone beneath fine-textured irrigated soils regardless of geographical location. Previous data showing nonpoint nitrate contamination were primarily confined to areas with coarse-textured soils. Both commercial and organic fertilizers were shown to leach.

Little nitrate movement was detected beneath active feedlots. Feedlot observations are thus in agreement with previously published reports.

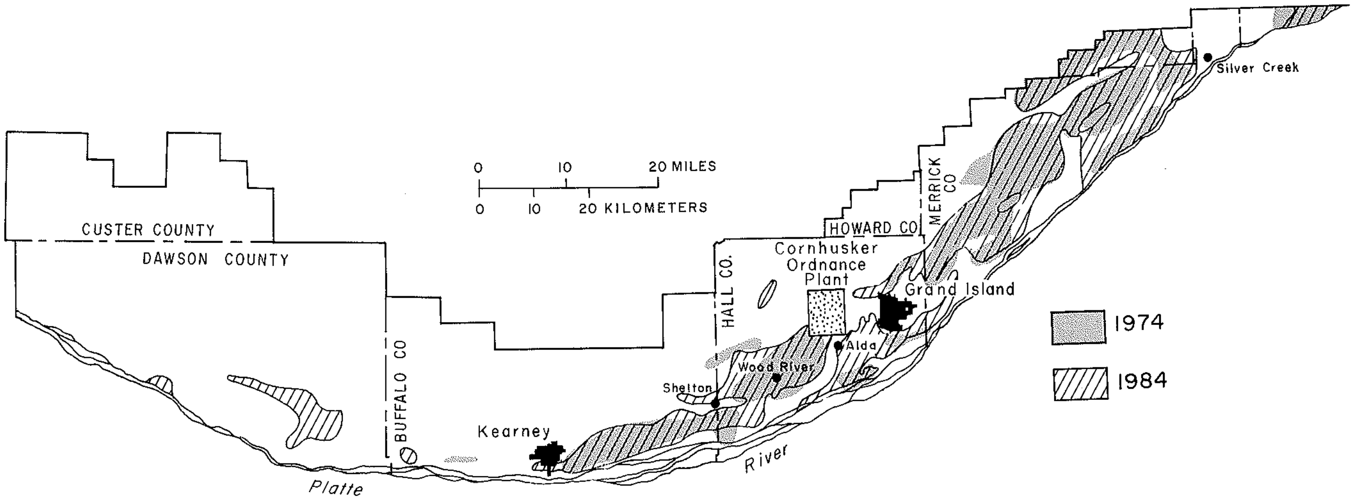
(I) Big Sandy basin recharge investigation - vicinity of Bruning

Surface water-groundwater interaction is being investigated at a recharge structure northeast of Bruning. The structure, located on a major tributary of Dry Sandy Creek, was built to impound surface water for groundwater recharge. Because the drainage area is primarily farmland, the runoff contains agronomic chemicals that could infiltrate to the saturated zone with the recharge water.

To obtain baseline chemical data for the groundwater near the structure, 15 household wells were sampled for nitrate and 27 pesticides. Nitrate-nitrogen concentrations were low in 14 of the 15 wells and averaged 1.1 parts per million. Since the surface water contains only very small quantities of nitrate-nitrogen, the recharge water would not have a degrading effect on groundwater nitrate-nitrogen levels. Atrazine, the only pesticide detected, was present in 12 wells but at very low levels (<0.1 part per billion).

Water-level measurements reveal that the recharge water is perched. The recharge water infiltrates through the sands and gravels until it reaches a sediment layer that is less transmissive than those above. The recharge water perches on a layer that water-level measurements indicate is continuous near the permanent pool.

Approximately 22,000 pounds of bromide were mixed into the permanent pool to trace the movement of the re-



Groundwater nitrate-nitrogen concentrations greater than or equal to 10 parts per million in the Central Platte Natural Resources District north of the Platte River

charge water. Significant concentrations of bromide were found in all the monitoring wells screened in the perched water table and in the wells screened in the upper part of the regional aquifer.

The pesticides alachlor (Lasso), atrazine, cyanazine (Bladex), and metolachlor (Dual), present in the surface water, have also been detected in the monitoring wells screened in the perched water table on the south and southeastern sides of the structure. These concentrations were lower than those found in the surface water of the recharge structure. Atrazine was found in many of the monitoring wells screened in the regional aquifer.

(J) Concentration of nitrate-nitrogen in groundwater in the Central Platte region, 1974-1984

A comparison of the 1974 and 1984 levels of nitrate-nitrogen shows the changes in the distribution of contamination in the Central Platte region. Between 1974 and 1984, a large area with nitrate-nitrogen concentrations in excess of 10 parts per million developed between Lexington and Overton. In 1974 large areal expanses of nitrate-nitrogen contaminated groundwater were found only east of Kearney.

By 1984, the areal extent of the nitrate-nitrogen contamination had increased east of Kearney. The gray zones (concentrations > 10 parts per million) spread, merging with other gray zones, and formed an almost continuous expanse of nitrate-nitrogen contaminated groundwater (striped zone) between Kearney and Silver Creek. The gray zone that stretched from Kearney to east of Shelton spread eastward and annexed the gray zone around Wood River, which also incorporated an area northwest and west that averaged 5.5 parts per million nitrate-nitrogen ten years earlier. The average nitrate-nitrogen concentration (22 parts per million) in this continuous striped zone from Kearney to west of Alda was significantly higher in 1984 than it was in 1974 (about 16 parts per million).

To determine the changes in nitrate-nitrogen levels in these two zones during the decade studied, the average 1974 concentrations were recalculated using only those wells sampled in both 1974 and 1984. Thirteen wells were resampled in the zone from Kearney to Shelton. The average concentration increased from 18 ± 7 parts per million in 1974 to 28 ± 10 parts per million in 1984. This represents an average annual increase of 1 part per million nitrate-nitrogen. In the striped zone surrounding Wood River, 22 wells were resampled, and the average concentration increased from 15 ± 5 parts per million to 23 ± 7 parts per million.

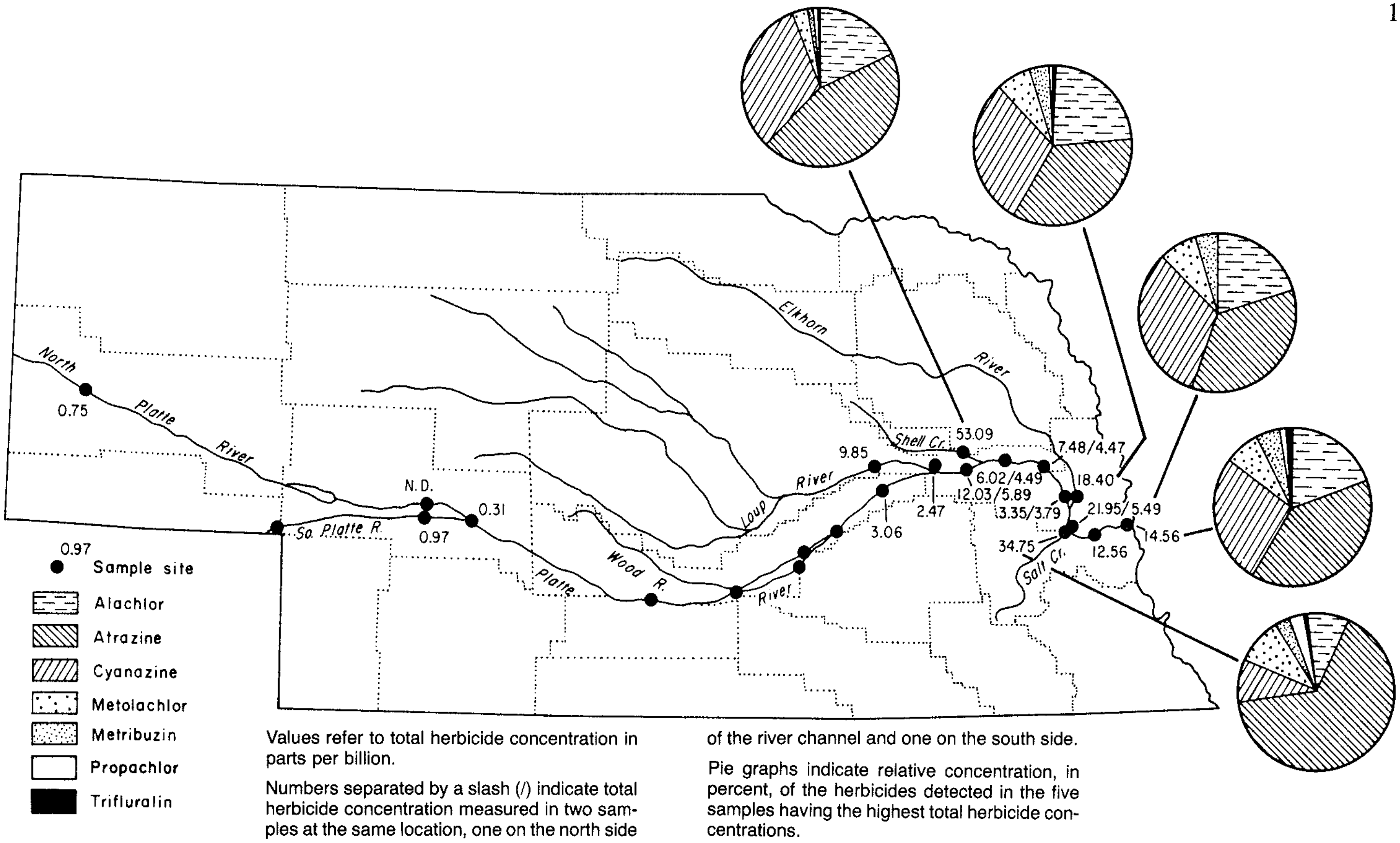
From Alda south to the Platte River and northeast to Grand Island, nitrate-nitrogen concentrations, ranging from 2.6 to 6.9 parts per million in 1974, increased to above 10 parts per million in 1984. This area merged with another gray zone south of Grand Island, which spread into southwest Merrick County in a area formerly underlain by groundwater with a nitrate-nitrogen concentration between 2.6 and 6.9 parts per million.

The large gray zone of high-nitrate groundwater in Merrick County expanded to the west and northeast; consequently, high nitrate-nitrogen levels became continuous from east of the Cornhusker ordnance plant to the extreme northeastern township of Merrick County. A recomputation of the 1974 average nitrate-nitrogen concentration for the 36 wells sampled in both studies and within the gray zone showed a significant increase in concentration from 22 ± 8 parts per million to 26 ± 11 parts per million, which is equivalent to an increase of 0.4 part per million per year.

The areas in which groundwater nitrate-nitrogen concentrations declined were small and in all but two instances occurred in areas where the concentrations were below 10 parts per million in 1974. Neither the size nor the average nitrate-nitrogen concentration of several large zones underlain by low nitrate-nitrogen groundwater (<6.9 parts per million) changed appreciably.

Regarding the methodology, every effort was made to

County	Number of wells sampled in 1974	Percentage resampled in 1984	NO_3-N (ppm) 1974	NO_3-N (ppm) 1984	Percentage NO_3-N >10 ppm 1974	Percentage NO_3-N >10 ppm 1984
Custer	15	60	3.9 ± 2.5	4.8 ± 3.4	0	0
Dawson	90	78	2.7 ± 2.7	4.4 ± 6.6	3	14
Buffalo	114	75	5.1 ± 6.8	7.3 ± 10.2	16	23
Hall	143	85	7.5 ± 6.9	10 ± 9	30	43
Howard	7	57	0.3 ± 0.2	1.2 ± 1.5	0	0
Merrick	121	77	12 ± 12	16 ± 13	46	63
Nance	9	78	5.4 ± 6.3	11 ± 7	14	57
Platte	9	89	14 ± 5	16 ± 12	75	50



Platte River study: pesticides in surface water, May 27, 1987

keep the two studies identical so as to accurately assess the change in areal distribution of the nitrate-nitrogen between 1974 and 1984. Consequently, the same wells sampled in 1974 were resampled in 1984, and the sampling was done at the same time of the year, between May and August.

Seventy-eight percent or 399 of the 511 wells sampled in 1974 were resampled.

(K) Lower Platte Valley groundwater and surface water study

The lower Platte Valley study is a multi-phase, 3-year study encompassing the Lower Platte North, Lower Platte South and Papio Natural Resources Districts.

Surface water

A possible pathway for contamination of groundwater by pesticides is via a river or stream contaminated by runoff from treated fields. Once in the river, dissolved pesticides can move into the groundwater in areas where the hydraulic gradient favors stream loss, or where infiltration galleries actively cause river water to seep into the ground. To assess the potential of this pathway for groundwater contamination in Nebraska, pesticide levels are being measured in samples taken at 28 locations along the Platte River and its major tributaries. Water samples were collected three times during the 1987 agricultural season and were analyzed for 23 pesticide residues. These samplings occurred in the early spring, during a period of high runoff and one of low flow, which was principally irrigation return flow.

The pesticide results of the sampling during high runoff are shown in the accompanying map. As expected, significant concentrations of many of the commonly used herbicides and one insecticide were present in the river after high runoff. The highest levels occurred in Shell and Salt creeks. Positive residue results are reported for the herbicides atrazine, alachlor (Lasso), cyanazine (Bladex), metolachlor (Dual), metribuzin (Sencor), propachlor (Ramrod) trifluralin (Treflan) and the insecticide terbufos (Counter).

Presently the impact of the residues on municipal supplies taken from Platte River alluvium is not known. It is thought that the levels will be diminished by sorption and filtration by the sediments between the well fields and the river. Although the sediments are rough filters, the chemicals may be sorbed to submicron-size particles and be partially filtered through the sediments and gravel pack.

Groundwater

At reducing fronts nitrate is removed by reduction to nitrous oxide and nitrogen gas, which are nontoxic. At these fronts, ions other than nitrate also undergo chemical changes. Data for some of these ions—iron, manganese and uranium—have been available since 1979. As part of this study, these data have been mapped to show areas where reducing fronts are suspected. This summer intensive dissolved oxygen measurements will be made to confirm the presence of the fronts and to define their boundaries. In addition, approximately 200 wells sampled for nitrates in 1978 and 1979 will be resampled and a rate of increase in nitrate-nitrogen concentrations determined. Additional samples will be taken adjacent to municipal well fields and in areas that are vulnerable to contamination. The vulnerable areas will be mapped out using the DRASTIC methodology. DRASTIC is a standardized, computerized method of evaluating the groundwater-pollution potential of hydrogeologic settings. (See related story on p. 2.) Much of the 3-NRD area has been mapped using this procedure.

Groundwater Quality and Policy Options in Nebraska

by Mary E. Exner
Research Chemist, CSD
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Research Hydrochemist, CSD

Editor's Note: The following article on groundwater quality and public policy in Nebraska is excerpted and reprinted from Nebraska Policy Choices, 1987, *a publication of the Center for Applied Urban Research at the University of Nebraska-Omaha. The publication is an annual volume of contributions by scholars and policy researchers. It seeks to identify current and emerging policy issues facing Nebraska; provide comprehensive analysis of policy choices around these issues and identify policy options; raise emerging policy issues for public discussion before they reach a critical stage; complement current state policy research by identifying innovative policies and strategies; and stimulate and encourage further policy research on these and other issues facing Nebraska. A copy of this year's or past volumes can be obtained by writing: Nebraska Policy Choices, Center for Applied Urban Research, University of Nebraska at Omaha, 60th and Dodge Streets, Omaha, Nebraska, 68182.*

Overview of Groundwater Quality in Nebraska

Introduction

Groundwater is vital to Nebraska. With the exception of the rural households serviced by the Cedar-Knox Rural Water District, which supplies surface water, groundwater satisfies the water-use demands of the entire rural population. Eighty-four percent of the public water supply demand is met with groundwater. Only Crawford and Blair and the small communities of Crofton and St. Helena are not served by groundwater. Chadron and the Metropolitan Utilities District, which serves the Omaha area, rely on both surface water and groundwater. Thus, 90 percent of the state's residents use groundwater for drinking water and other domestic needs. Seventy-two percent of the irrigation needs and 85 percent of the self-supplied industrial needs are met with groundwater. Because this natural resource is essential to the development of the state, its quality must be maintained.

Quality describes the physical, biological, chemical and radiological characteristics of groundwater. The assessment of the quality, however, is dependent upon the intended use, because the importance of each property is relative to the intended use and the user.

In general, the public probably assesses drinking water quality based on properties that can be evaluated by personal experience, such as taste, odor and appearance, and on media hype. Seventy-seven percent of the respondents to the 1986 Nebraska Annual Sociological Indicators Survey thought there were "man-made chemicals in the drinking water which could affect their health." Seventy-six percent ranked the problem as a serious or moderately serious one. In an ironic twist, residents of southeastern Nebraska thought the problem was less serious than other Nebraska residents. The survey researcher attributed this to the large urban population, which has less direct exposure to water-quality problems than rural and small community residents. The highest regional frequency of point-source contamination in Nebraska occurs in the southeastern part of the state. This contamination primarily affects rural residents.

Regulatory agencies like the Nebraska Department of Environmental Control (NDEC) and the Nebraska Department of Health (NDOH) define water quality in terms of its conformity to U.S. Environmental Protection Agency (EPA) drinking water standards. All public drinking water supplies, those regularly serving a minimum of 25 people or having at least 15 service connections, must meet these federal drinking water standards. Also known as maximum contaminant levels (MCLs), these enforceable criteria establish the maximum permissible concentration of a contaminant in the public water supply.

Nebraska, like most other states, has adopted the federal drinking water standards as groundwater-quality standards. The rationale for this decision is that most of the groundwater in the principal aquifer in Nebraska is of drinkable quality, and it is a source of drinking water for most of the populace; therefore, protecting the groundwater for use as drinking water usually protects it for all uses. The contaminants that are regulated in Nebraska and their MCLs are listed in two accompanying tables. From these tables it is evident that the EPA has promulgated very few MCLs, although 83 contaminants are to be regulated by 1989. Because EPA standards, especially those for organic compounds, have been developed at a slower rate than the chemicals have been detected in drinking water, a few states have established groundwater-quality standards or health advisories for compounds without MCLs. California, Florida, New York, Massachusetts and Wisconsin have adopted additional water-quality criteria.

Primary groundwater-quality standards and established maximum contaminant levels (MCLs)

Contaminant	MCL	Physiological Effect
Inorganic chemicals (milligrams per liter)		
Arsenic	0.05	toxic, carcinogen ?
Barium	1.0	toxic
Cadmium	0.01	toxic; carcinogen ?
Chromium	0.05	carcinogen ?
Fluoride	4.0	dental mottling
Lead	0.05	carcinogen ?; teratogen
Mercury	0.002	toxic
Nitrate-nitrogen	10	methemoglobinemia
Selenium	0.01	suspected carcinogen
Silver	0.05	skin discoloration
Organic chemicals (micrograms per liter)		
Endrin	0.2	carcinogen
Lindane	4	carcinogen
Methoxychlor	100	teratogen
Toxaphene	5	toxic
2,4-D	100	carcinogen
2,4,5-TP Silvex	10	carcinogen; teratogen
Total trihalomethanes	100	carcinogen
Radionuclides (picocuries per liter)		
Radium-226 & radium-228	5	carcinogen
Gross alpha cavity (includes Ra-226; excludes radon & uranium)	15	carcinogen
Gross beta activity	50	carcinogen

Primary Source: Nebraska Department of Environmental Control, Title 118 - Ground Water Quality Standards and Use Classification, November 22, 1986.

Secondary groundwater-quality standards and established maximum contaminant levels (MCLs)

Contaminant	MCL (milligrams per liter)	Aesthetic effect
Chloride	250	taste
Copper	1	taste
Iron	0.3	stains
Manganese	0.05	stains
Sulfate	250	taste
Zinc	5	taste

Primary Source: Nebraska Department of Environmental Control, Title 118 - Ground Water Quality Standards and Use Classification, November 22, 1986.

Overview of Groundwater Quality

Because chemicals are widespread in the environment and most chemicals are at least slightly soluble in water, contaminants can be transported to the aquifer by recharge. Recharge, which is water reaching the surface of the water table, is a primary influence on groundwater quality in Nebraska. Sources of recharge include bodies of surface water, such as rivers, lakes, streams, canals, reuse pits and lagoons; infiltrating precipitation; and irrigation water.

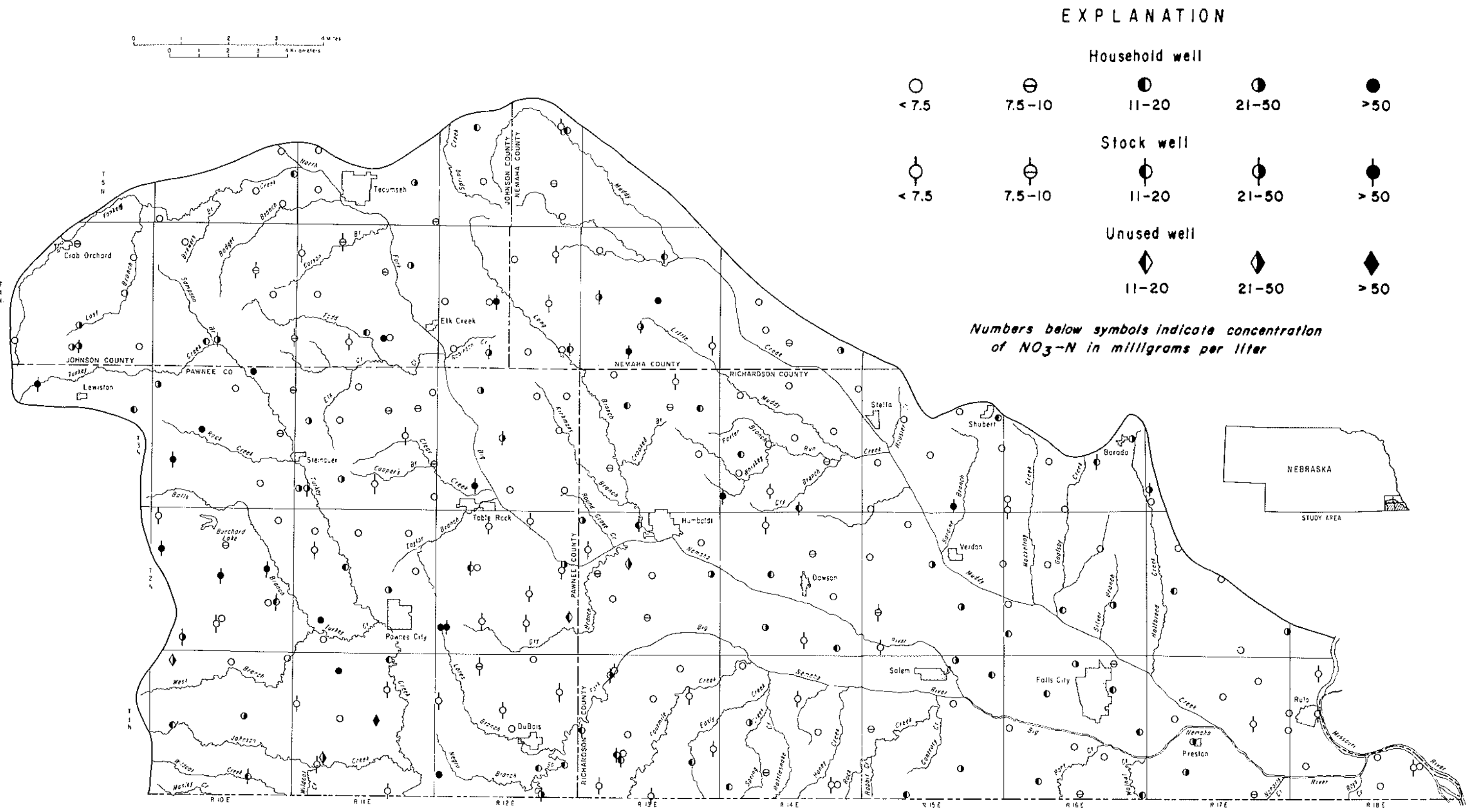
Chemical contaminants can occur naturally, or they can be anthropogenic, that is, introduced by man. Major naturally occurring contaminants are derived from the breakdown of minerals (salts) and organic matter in the soil, and from the dissolution of minerals in the unsaturated and saturated zones. Anthropogenic contaminants include chlorinated organic solvents, metals, nitrates and pesticides. Whether natural or anthropogenic, the source of the contaminant can be described as line, point or nonpoint. Chemicals can seep into aquifers along the length of a waterway (a line). Hence rivers, streams and canals are potential line sources of contamination. Point sources originate at discrete locations such as disposal pits, lagoons, abandoned feedlots, wells, spills, landfills, surface impoundments and underground storage tanks. Nonpoint contamination is dispersed over an area. Fertilizer and pesticides applied to fields and precipitation are potential nonpoint sources.

Line Sources of Contamination

The Platte River is by far the most important line source of recharge in Nebraska. Because the public supply wells of most towns and cities along its 500-mile path in Nebraska pump groundwater from the Platte River alluvium, the wells, in essence, are pumping considerable amounts of Platte River water. An estimated 40 percent of Nebraska's population served by public water supplies relies on this alluvial aquifer, which is composed of sediments deposited by the Platte River. Although potable, water in the Platte River and in the alluvium generally contains higher concentrations of many naturally occurring chemicals than water pumped from most of the state's shallow aquifers. This chemical load, known as total dissolved solids (TDS), is a measure of the amount of mineral matter dissolved in the water. The elevated TDS in the groundwater surrounding the North Platte, South Platte and Platte Rivers [probably] indicates that there is lateral seepage of canal and river water. The pumping of irrigation wells in the Platte Valley exacerbates this transfer, as does recharge from canal-irrigated bottomland.

Pesticides in runoff from treated fields appear to be the greatest anthropogenic threat to drinking water derived from the infiltration of water from the Platte River. Recently, low levels of the herbicides atrazine, alachlor (Lasso), cyanazine (Bladex), and trifluralin (Treflan) and the insecticide carbofuran (Furadan) were identified in the Des Moines, Iowa, water supply. Because Des Moines derives its drinking water supply from infiltrated Des Moines River water, an analogous situation could be present in Nebraska. The Conservation and Survey Division in the Institute of Agriculture and Natural Resources of the University of Nebraska-Lincoln currently is sampling the Platte River and its tributaries at 28 locations between Scottsbluff and Omaha. Preliminary

Areal distribution of concentrations of nitrate-nitrogen in lower Nemaha basin groundwater, Nebraska



Source: M. Exner, C. Lindau and R. Spalding; "Ground-Water Contamination and Well Construction in southeast Nebraska," Ground Water 23 (1985):26-34.

data obtained during a high runoff event in the spring indicate the presence of several pesticides in part per billion quantities. These concentrations appear related to runoff from unimproved croplands.

Point Sources of Contamination

While point sources of groundwater contamination generally result from human activities, many times natural processes occurring within the aquifer cause local groundwater contamination. Within these relatively small areas, low oxygen levels in the groundwater favor reactions that solubilize metals contained in minerals in the aquifer or [reactions] that produce gases. High concentrations of iron, manganese, uranium, radon, and hydrogen sulfide can be produced. In some cases, changing the depth of the well screen or the areal siting of the well will improve the situation. While the health effects caused by ingesting water with high levels of radon (decay product of radium) and uranium are questionable, elevated concentrations of hydrogen sulfide, iron, and manganese are primarily a nuisance. High concentrations of radium and uranium in groundwater occur in the basal Chadron unit beneath Crawford and in the basal Pleistocene near Alda in Hall County. Hydrogen sulfide, iron and manganese make groundwater less attractive by imparting odor (rotten egg smell from hydrogen sulfide), taste (a bitter taste to coffee and other beverages from iron and manganese) and stains (iron and manganese). While these nuisance chemicals are removed from most public water supplies, they remain the principal water-quality concern for many rural Nebraskans. As more domestic wells are drilled deeper to avoid agricultural contaminants at the top of many aquifers, the number of iron, manganese and hydrogen sulfide complaints [probably] will increase.

There is a long and growing list of anthropogenic point sources of groundwater contamination in Nebraska. Some of these sources have been causing problems for the past 70 years; others have been discovered only recently. These contaminants are associated with agriculture; petroleum storage; munitions production; solid and hazardous waste disposal; and a multitude of industries, ranging from dry cleaning plants to heavy equipment manufacturing.

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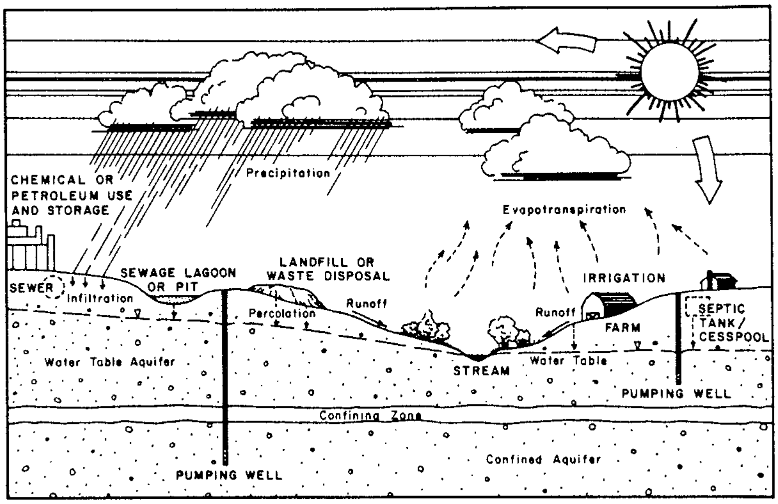
Since the late 1940s, sporadic elevated nitrate levels have been reported in the groundwater of the eastern quarter of Nebraska. A recent study of the lower Nemaha basin (in extreme southeastern Nebraska) in 1985 showed that 71 percent of the 268 sampled wells had nitrate-nitrogen concentrations above 10 parts per million (ppm) and/or coliform bacteria. The areal distribution of the nitrate concentrations was indicative of point-source contamination. Leachates from animal wastes were the major contaminant; siting and construction of the contaminated wells were inadequate to protect the integrity of the water supply. The incidence of nitrate-nitrogen contamination, that is, wells with more than 10 ppm nitrate-nitrogen, in this 1,100-square-mile area was 37 percent. This is similar to the frequencies (22 and 18 percent) reported in two areas of about 7,200 square miles in eastern Nebraska with point-source nitrate-nitrogen contamination. These data indicate that nitrate is the most widespread groundwater contaminant in rural eastern Nebraska.

Chemigation systems provide a direct route for contamination of the groundwater by pesticide or fertilizer concentrates if the backflow-prevention equipment fails, or if the system is operated illegally without a check valve.

According to the NDOH, rural incidences of nitrate contamination throughout the eastern quarter of Nebraska increased between 1979 and 1984. Eighteen of the 26 towns in Nebraska in violation of the nitrate-nitrogen MCL were in the eastern quarter of the state. In nonirrigated areas these elevated concentrations probably result from point-source nitrate contamination.

Although much of the nitrate contamination in the eastern quarter of Nebraska originates as point sources, new evidence suggests that nitrate from nonpoint sources can contaminate the groundwater beneath irrigated fields even in areas where the unsaturated zone sediments are predominantly fine-textured silts and clays. Previously, researchers thought that even under irrigation significant quantities of nitrates did not pass through thick layers of fine-textured sediments; consequently, most groundwater in the eastern quarter of Nebraska was assumed much less likely to be contaminated by nonpoint sources of nitrate. In general, nitrate levels in the eastern quarter of Nebraska are higher in groundwater contaminated by point sources than in groundwater contaminated by nonpoint sources. This is a response to the higher levels of nitrate in the leachate from point sources and the lack of groundwater available for dilution because of the thinness of the aquifer.

The potential for nitrate contamination from manure-covered soils is dependent upon the animal density in the barnyard or feedlot. Nitrate-nitrogen is less likely to accumulate in the deep soil profile of feedlots that are always stocked. These soils have an undisturbed and continuously accumulating manure pack, where hoof compaction and excreted urine keep the surface sealed, damp and reducing. In this environment conversion of ammonia to nitrate is unlikely.



Potential sources of groundwater pollution

When the feedlot is abandoned, surface drying and cracking promote conversion of urea to nitrate and the subsequent leaching of nitrate through the unsaturated zone and, ultimately, to the [aquifer]. Because most barnyards and corrals are not stocked in the summer, the physical and chemical processes occurring in the manure pack would parallel those in an abandoned feedlot.

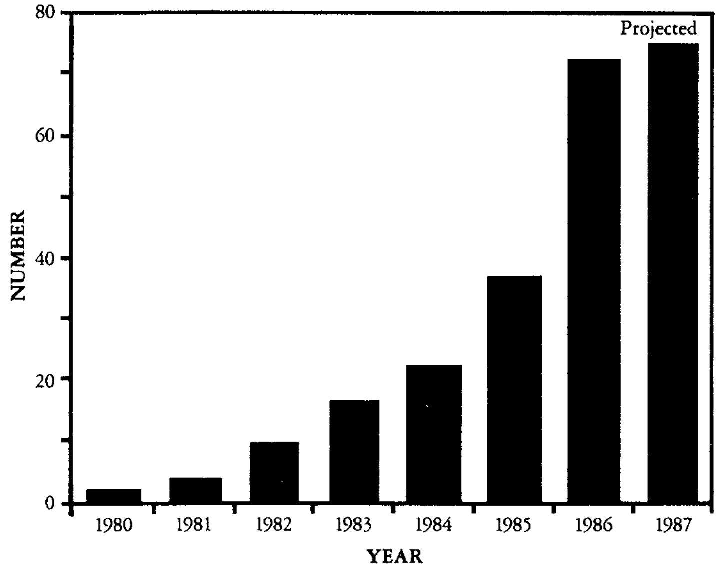
Few cases of point-source pesticide contamination have been reported to NDEC although several have occurred. Most of the accidents occurred when chemicals were applied near surface waters that were in hydraulic connection with the groundwater or when the chemical was back-siphoned from a mixing tank and was injected directly into the groundwater. One of the first documented cases occurred in Kimball in 1969. The herbicide picloram (Tordon), allegedly sprayed on weeds around a waste lagoon, contaminated the municipal water supply and caused the demise of several hundred greenhouse tomato plants. A similar event occurred in Bassett in 1975. Trace levels of arsenic in the municipal water were attributed to the use of an arsenic herbicide around the municipal sewage lagoon. These two examples illustrate the incompatibility of siting wells near lagoons.

Since 1980, the Nebraska State Fire Marshal has responded to 88 life-threatening incidences caused by fuels migrating into sewer systems or home basements. During this same period, the Nebraska Department of Environmental Control investigated 186 fuel leaks that either were not life-threatening or occurred within the seven largest cities.

Farmers have been known to contaminate their domestic water supplies when mixing pesticides. Back-siphoning occurs when the water hose remains in the pesticide mixing tank and the well pump shuts down. The contents of the mixing tank subsequently are siphoned into the well.

Back-siphoning during chemigation is a potentially severe contamination problem. Chemigation is the application of chemicals, usually pesticides or fertilizer, to crops through an irrigation system. Basically, the concentrated chemical

Number of leaking underground fuel storage tanks reported to NDEC



Source: W. Imig, Nebraska Dept. of Environmental Control May 14, 1987.

is metered into the irrigation water and applied with the water. Chemigation systems provide a direct route for contamination of the groundwater by pesticide or fertilizer concentrates if the backflow-prevention equipment fails, or if the system is operated illegally without a check valve.

Recently, leaky underground storage tanks have become a source of concern as point sources of contamination. In Nebraska, most of these tanks contain leaded and unleaded gasoline and diesel fuel. Industrial solvents are stored in a few tanks. As early as 1960, however, gasoline contamination was reported in an aquifer in Nebraska. Tens of thousands of gallons of gasoline were floating on the water table near and beneath the Swift Company plant in Gering. Since 1980, the Nebraska State Fire Marshal (NSFM) has responded to 88 life-threatening incidences caused by fuels migrating into sewer systems or home basements. During this same period, the NDEC investigated 186 fuel leaks that either were not life-threatening or occurred within the seven largest cities. Both agencies expect an increase in the number of reports of leaky fuel tanks in the next 2 years as more station owners become aware that procrastination in reporting leaks results in more extensive contamination and more costly cleanup.

Gasoline and diesel fuel are organic compounds that do not dissolve in and are lighter than water; consequently, the fuel is found at the water table. Although the fuel remains relatively stationary, there are water-soluble compounds in the fuel. The presence of these compounds (benzene, toluene and xylene) in the groundwater usually indicates petroleum contamination. Because relatively large quantities of these compounds can be dissolved in the groundwater and move with the flow, serious groundwater-quality problems can develop, and they are of much more concern than the immobile fuel. Nine municipalities in Nebraska have trace levels of one or all three compounds in either a public supply well or in monitoring wells in the vicinity of the public supply wells. In these instances, the sources are most likely leaky underground storage tanks at gas stations or surface spills. In Nebraska there have been at least two incidences of groundwater contamination from leaky storage tanks containing the pure industrial solvents toluene and xylene.

Another class of groundwater contaminants receiving much press are liquids that do not readily dissolve in water and are heavier than water. These organic compounds are volatile and most contain chloride. Like the fuel-derived compounds, benzene, toluene and xylene (BTX), these compounds are soluble enough in water that the concentrations can have serious groundwater-quality implications; but, unlike BTX, these compounds sink through the saturated zone and reside at the bottom of the aquifer. These compounds are used primarily as degreasers, grain fumigants and paint removers. In Nebraska, trichloroethylene (TCE), carbon tetrachloride and tetrachloroethylene (PCE) are the most frequently found compounds of this type in the groundwater. TCE, PCE or both have been identified in groundwater beneath 13 towns or municipalities, while traces of carbon tetrachloride were found in groundwater beneath 20 other towns.

Waste-disposal sites at ordnance facilities that manufactured munitions also have contaminated the state's groundwater. A 3-mile plume of RDX (Research Department Explosive) and a 1-mile plume of TNT have been traced to the decommissioned Cornhusker Army ordnance facility west of Grand Island. As part of the remedial action presently being undertaken, contaminated soils at the suspected source areas are excavated and incinerated to remove the munition residues. The costs for cleanup and extending the municipal water supply to homes in the affected area are approaching $10 million.

In Nebraska, 36 landfills are licensed to accept municipal waste. Because second-class cities and villages have been exempt from landfill-licensing requirements since 1972, the Nebraska Department of Environmental Control estimates there are 350 to 400 open dumps in the state. Certainly some of these dumps and landfills are contaminating the groundwater, but the impact on local groundwater quality is unknown.

Munitions were manufactured at three other ordnance facilities in Nebraska. All three have been abandoned. Both groundwater and soil are being monitored at the former Army ammunition plant at Mead and the former Navy ammunition depot east of Hastings. Monitoring of soil and groundwater at the former Sioux ordnance facility north of Sidney is not planned in the near future.

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Nonpoint Sources of Contamination

Nonpoint contamination results from the dissolution of a widespread, relatively uniform source that can be of natural or anthropogenic origin. It results in large areas of contaminated groundwater with relatively uniform concentrations.

In Nebraska, naturally occurring nonpoint contamination occurs where metals and other chemicals in aquifers with poor quality water are solubilized and migrate into the aquifer from which a potable water supply is drawn. These chemicals also can be present in saturated sediments that do not produce recoverable quantities of groundwater and migrate into the producing aquifer.

Significant selenium contamination occurs in the groundwater in areas of Boyd, Keya Paha and northern Holt counties. In these areas the water-bearing sediments are thin and yield small quantities of groundwater. In order to ensure an adequate supply of water is available, wells are drilled into the bedrock to provide additional storage space for water. The creation of this reservoir can mobilize selenium in the bedrock. Moderately high selenium concentrations also occur in groundwater in some parts of the Dakota Aquifer, the principal source of potable groundwater in eastern Nebraska. Volcanic ash beds in northwestern Nebraska are a third source of moderately high selenium concentrations in the groundwater.

The distribution of high fluoride concentrations in the groundwater is quite similar to that of selenium, indicating that both chemicals are derived from similar source rocks. Except in isolated cases, the concentrations of these naturally occurring, nonpoint contaminants are not severe enough to cause health problems.

[Virtually] all anthropogenic nonpoint contamination in Nebraska is related to agriculture, which is the state's largest industry. In 1986 this industry used 1.6 billion pounds of nitrogen fertilizer in Nebraska. In 1984, the last year for which statistics are available, 30 million pounds of pesticides were applied to Nebraska farmland. Poor management of these agrichemicals and irrigation water has resulted in nonpoint groundwater contamination.

The short distance to the water table (less than 20 feet), large areas of well-drained to excessively well-drained soils and intensive fence-row to fence-row, irrigated-corn agriculture make areas of the Central Platte Natural Resources District (NRD), northern Holt County and an area west of Sidney the most vulnerable to nonpoint agronomic groundwater contamination in Nebraska. Groundwater underlying large areas of the Central Platte NRD is contaminated with fertilizer-derived nitrate. Between 1974 and 1984, the area with nitrate-nitrogen concentrations greater than 10 ppm increased, as did the average nitrate-nitrogen concentration of the contaminated groundwater. In Holt County nonpoint nitrate-nitrogen contamination from fertilizer occurred north of the Elkhorn River in areas of intensive irrigation development. Because of the low chemical load of this Sand Hills-type groundwater, additions of sulfate and chloride from potash and sulfamag fertilizers were also apparent in the groundwater. Another area of nonpoint nitrate contamination appears to be developing west of Sidney. Presently, this area, smaller in areal extent than the other two areas, is the site of a detailed investigation by the Conservation and Survey Division.

Areal nitrate contamination in the central Platte area, northern Holt County and west of Sidney may be only the tip of the nonpoint nitrate-contamination iceberg. Additional investigations in areas of southeast and south-central Nebraska with fine-textured, irrigated soils indicate that in 13 years the nitrate has moved at least 65 feet through an unsaturated zone of predominantly silt and clay. One must conclude that all nitrogen-fertilized, irrigated areas in Nebraska could be subject to nitrate pollution if better fertilizer and water management is not practiced. Most of the nitrate-contaminated wells in the Central Platte NRD also contained trace levels of atrazine, which has been statistically correlated with the nitrate concentrations. Some wells also tested positive for alachlor (Lasso).

Nebraska's Policy Response to Groundwater Contamination

(adapted from *Nebraska Policy Choices*)

From the preceding overview, it is apparent that the quality of the groundwater has deteriorated in many areas of Nebraska, that the quality in these areas continues to worsen, that new areas of contamination will occur and that there are many potential sources of contamination that can affect groundwater quality. The public-policy responses to the deterioration of Nebraska's groundwater include doing nothing, educating residents and regulating contamination.

Historical Perspective of Public Policy

Until the 1980s, comprehensive programs protecting the quality of groundwater in Nebraska were virtually nonexistent. In the early 1970s, research and educational programs were just beginning to address agronomic nonpoint nitrate contamination of the groundwater. Although research showed that changes in agricultural practices had the potential to improve groundwater quality without compromising crop yields, the agricultural community was reluctant to implement these recommendations. Legislation and judicial decisions reflected the impetus in the development of groundwater reserves for irrigation. Rules and regulations that were promulgated were directed at specific point sources of contamination. None of the policy goals, however, was aimed at preserving the integrity of the vastly uncontaminated supply.

The first policy-issue study addressing groundwater quality was completed as part of the State Water Planning and Review Process initiated in 1978 and 1979. This policy-issue study did not result in any new legislation.

In 1983, Governor Kerry formed a Water Independence Congress to develop a set of principals and specific recommendations for developing a water policy for the state. The 40-member congress had diverse economic, political, philosophical and professional backgrounds and represented every geographic area of Nebraska. Two specific recommendations were to clarify and modify the law addressing backflow-prevention devices on chemigation systems and to regulate chemical and petroleum storage.

Regulation of Potential Line Sources of Contamination

Surface-water quality must comply with standards set by NDEC. The use of surface water dictates the set of criteria that are enforced. As already mentioned, the most important line source for groundwater recharge in Nebraska is the Platte River. It has been given an agricultural rather than a public drinking-water supply use classification because municipalities do not supply treated water from the river, but, instead, obtain infiltrated river water from wells on islands in the river or along the river. The general criteria for water with an agricultural classification prohibit the presence of waste or toxic substances that have undesirable effects in crops or livestock. The only numerical criteria are for conductivity, a measurement used to approximate total dissolved solids and nitrate-nitrogen.

Regulation of Potential Point Sources of Contamination

1894—The Nebraska Supreme Court ruled in *Beatrice Gas Company vs. Thomas* that landowners were entitled to protection of their drinking water from contamination, and, under a private nuisance theory, that one who pollutes his neighbor's drinking water supplies was liable for the damages caused.

1961—Legislation was passed requiring abandoned irrigation wells to be sealed to prevent contaminants from reaching groundwater.

1971—The Unicameral enacted the Nebraska Environmental Protection Act. This legislation consolidated environmental responsibilities from a variety of state agencies into the Nebraska Department of Environmental Control (NDEC). Such an agency enabled the state to use federal technical and financial assistance more effectively. The NDEC was given broad authority to protect Nebraska's groundwater quality. It wrote rules and regulations for some potential point-source contaminants in its early years.

1972—The state legislature recognized the potential for severe and imminent contamination should an irrigation pump accidentally shut off on a system used to apply water and fertilizer simultaneously. The statute required that "fertigation" systems be equipped with a backflow-prevention device. This device is designed to prevent siphoning of the contents of the fertilizer tank into the irrigation well and, subsequently, into the aquifer if the irrigation pump fails. This statute later was revised in 1977 to require backflow-prevention devices on irrigation systems used to apply pesticides.

1978—The NDEC adopted the federal primary and secondary drinking water standards for Nebraska's groundwater and applied them to groundwater with a TDS concentration of less than 10,000 milligrams per liter. Primary standards were set for contaminants that are hazardous or produce undesirable physiological effects on humans, animals and plants. Maximum contaminant levels (MCLs) were adopted for ten inorganic compounds, six organic compounds, radium, gross alpha activity and gross beta activity. Secondary standards are applied to constituents that impart odor, color or taste to the water and are aesthetically undesirable. [See tables on p. 15.]

1986—The Nebraska Chemigation Act was passed. A comprehensive law regulating the application of farm chemicals through irrigation systems, it detailed the safety equipment required on each chemigation system with equipment specifications to be adopted by the NDEC and required chemigator certification and a permit to operate the system. NRDs, under NDEC supervision, were charged with enforcement.

1986—The Petroleum Products and Hazardous Substances Storage and Handling Act provided for registration and inspection by the Nebraska State Fire Marshal of storage tanks for petroleum products and hazardous substances and established a cleanup fund for orphaned tanks. Primary responsibility for administration was given to NDEC.

1986—Nebraska's groundwater-protection standards (Title 118) were revised. In the new NDEC document, *Ground Water Quality Standards and Use Classification,* EPA's new numerical quality criteria were adopted; all groundwater in the state was classified based on its present or potential use as a drinking water supply. By 1989, these criteria will include standards for 14 volatile organic chemicals, 24 inorganic and 39 organic compounds, 5 microorganisms and 5 radionuclides. The criteria are the basis for regulatory programs and remedial action and mostly apply to all groundwater that has any potential as a public or private drinking water supply.

In Title 118, NDEC also has established a Groundwater Remedial Action Protocol to handle present or potential point-source contamination of groundwater. The protocol determines the type and the extent of the action necessary to mitigate contamination. The necessary action is dictated by remedial action classes (RACs).

Regulation of Potential Nonpoint Sources of Contamination

1975—Nonpoint-source contamination was first addressed in the Groundwater Management Act (GMA). The principal intent of the GMA was to slow or reverse groundwater mining by authorizing NRDs to request designation of a groundwater-control area from the director of the Nebraska Department of Water Resources (NDWR). Groundwater-quality control areas, however, could be designated if the development and use of the groundwater had caused or was likely to cause quality problems resulting from dewatering of an aquifer.

1979—The Lower Loup NRD requested designation of a groundwater-control area in part because of deterioration of groundwater quality. The request was denied by the NDWR director. One reason for the denial was that the chemical degradation of the groundwater supply had not resulted, nor was it anticipated to result, exclusively from the dewatering of the groundwater reservoir.

1979—Although it did not lead immediately to new regulations, the Hall County Water Quality Special Project was an important study undertaken cooperatively by the Central Platte NRD, the University of Nebraska and federal agencies. It sought to demonstrate in western Hall County that groundwater nitrate-nitrogen levels could be maintained or reduced through improved nitrogen and water management. When the voluntary program concluded after 4 years, it was reported that the groundwater nitrate-nitrogen levels had stabilized.

1981—Further revision of the Groundwater Management Act produced the Groundwater Management and Protection Act (GWMPA). This act vested NRDs with the sole authority to request designation of groundwater-quality control areas from the director of the NDWR to prevent current or foreseeable pollution. No longer did the pollution need to be related to dewatering an aquifer. If a control area was designated, the statute authorized the NRD, with NDWR approval, to implement corrective measures that would mitigate or eliminate the condition that led to the contamination.

1982—Subsequent revisions of the GWMPA authorized NRDs to establish groundwater-management areas and to implement controls without NDWR approval upon completion of a groundwater-management plan and its review by the NDWR director. While areas of groundwater-quality concern were to be identified in the plan, the authorized controls (allocation of total withdrawal, rotation of use, well-spacing requirements and the use of flow meters) were more effective in regulating withdrawals than in protecting quality.

1984—The director of the NDWR approved regulations proposed by the Upper Republican NRD to protect groundwater quality in a (quantity) control area established in 1977. The NRD required annual permits for each chemigating system. The system needed a properly functioning check valve and a device to shut off the injection pump when the irrigation pump shut off to qualify for the permit. It is noteworthy that the only quality-control area designation was instituted for a potential point-source contaminant.

1984—LB 1106, an outgrowth of the Water Independence Congress, required each NRD to prepare a groundwater-management plan. Implementation, however, was optional. All the NRDs have written groundwater-management plans, except the Upper Republican NRD, which the NDWR exempted because almost the entire district is a groundwater-control area.

1986—The Unicameral made sweeping revisions of the GWMPA. For the first time, nonpoint-source contamination was seriously addressed in the statutes. LB 894 had two major provisions. First, an NRD could propose a groundwater-management area primarily to *protect* water quality. This provision eliminated control-area designation based solely on *deterioration* of groundwater quality. Second, the NDEC received the authority to designate special groundwater-protection areas.

If a management area is proposed primarily to protect water quality, the plan must also be reviewed by the NDEC. Best management practices (BMPs) and attendance at educational programs designed to protect water quality were added to the three control measures already authorized by the GWMPA. BMPs are the "scheduling of activities, maintenance procedures, and other management practices utilized to prevent or reduce present and future contamination of groundwater, which may include irrigation scheduling, proper timing of fertilizer and pesticide application and other fertilizer and pesticide-management programs."

The second provision of LB 894 is a significant departure from the local-option philosophy that has dominated the GWMPA. While the statute recognizes that NRDs "as local entities are the preferred regulators of activities which may contribute to (nonpoint) contamination in both urban and rural areas," it also authorizes the NDEC to regulate sources of contamination when necessary to prevent serious deterioration of groundwater quality.

1987—The Central Platte NRD implemented a model groundwater-management plan with extensive controls within designated groundwater-quality management areas. Controls within the management areas are dependent on the concentration of nitrate in the groundwater. The regulations include banning the application of commercial nitrogen fertilizer on sandy soils during fall and winter; restricting commercial nitrogen fertilizer application until after November 1 on soils that are not sandy, and then allowing applications only with the use of an inhibitor approved by the NRD board and applied at their approved rate; annually analyzing the nitrogen content of soils and irrigation-well water; requiring certification of attendance at district-developed or approved education programs on BMPs; and annual reporting of nitrogen concentrations in irrigation-well water and soils, of crop to be grown and yield goal, of recommended nitrogen fertilizer application rate, of amount of commercial nitrogen applied to each field and of actual yield obtained.

Policy Strategies

—Opinion—

Nebraska's groundwater-quality policy has been fragmentary and, generally, a reactive policy; that is, the programs are either corrective and respond to known contamination problems or are a response to new EPA policies and regulations. Because the policies have been corrective, they lack the long-range planning characteristic of a groundwater-protection program. Legislative changes must occur if the policies, particularly those regarding nonpoint contamination, are to protect the quality of the groundwater resource. NDEC's Groundwater Quality and Use Classification, which addresses point-source contamination, is weaker than their draft Groundwater Protection Strategy. In order to protect groundwater from point-source contamination, the rules and regulations for each potential point source must be rewritten in stronger language.

Nonpoint Nitrate Contamination

Nitrate contamination of the groundwater from nonpoint sources will become worse because nitrate-nitrogen concentrations will continue to increase in the contaminated areas and new areas of contamination are anticipated. Implementation of protective measures permitted in groundwater management or special protection areas (SPAs) will not have an immediate effect on nitrate-nitrogen levels in the groundwater. Because nitrate is still present in the unsaturated zone, it will take time for this nitrate to reach the aquifer. Also, the nitrate levels in the groundwater will not decrease unless the contaminated groundwater is used for irrigation and the nitrate utilized by plants. Nitrate contamination can be anticipated in irrigated areas with fine-textured soils. Although nitrate is predicted to move at a slower rate through thick layers of unsaturated sediments than through coarser textured sediments, eventually the nitrate will reach the aquifer.

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A variety of options are available for dealing with nonpoint nitrate contamination. Three are related to controlling the source of contamination, and the fourth to land-use. The first option is to continue the farming practices responsible for the nonpoint contamination and be resigned that the nitrate levels in the groundwater and the areal extent of the contamination will increase. Atrazine concentrations will most likely increase, and other pesticides may become detectable in the groundwater.

The second option is education and implementation of best management practices (BMPs). The success of this option in reducing nitrate concentrations in the groundwater is debatable. During the last decade, farmers in areas of the Central Platte NRD had the opportunity to participate in a program (technical information, expertise and field measurements of crop needs were supplied) that could help decrease the amounts of nitrogen fertilizer moving below the root zone. The efficacy of this option relies on farmers' voluntary compliance with BMPs, the number of acres in the program and the duration of the farmers' participation.

Stricter regulations are the third nonpoint-source control option. While present statutes may require use of BMPs in management areas or SPAs underlain by nitrate-contaminated groundwater, regulation of fertilizer application rates could be necessary. Because there is no substitute for nitrogen fertilizer, restricting the amount of fertilizer used in areas underlain by nitrate-contaminated groundwater would put farmers within the area at an economic disadvantage. Such a policy would be highly discriminatory, but an effective program probably will require the implementation of BMPs and regulation of fertilizer-application rates.

Land-use restrictions are a viable alternative to nonpoint-source nitrate control. Activities that have the potential to pollute the groundwater could be prohibited in designated areas. Groundwater in these areas would serve as the potable water supply for areas where the groundwater is contaminated. In essence, polluting activities would be permitted in certain areas, the groundwater quality would be permitted to deteriorate and the groundwater would be written off as a potable supply. Preservation of sections of the Sand Hills and other pristine areas with good quality groundwater would assure those in nonpoint contaminated areas of a continuous supply of potable water. Such a solution eliminates balancing the cost-benefit ratios of production and regulation in areas that currently have nonpoint nitrate contamination or projected water-quality problems.

Several municipalities have purchased islands in the Platte River for their well fields. This was a conscious decision to avoid nitrate contamination by utilizing natural physical barriers. This strategy has worked well; however, the promulgation of new maximum concentrations for contaminants (for example, uranium) present in Platte River water could cause problems for these municipalities.

Nonpoint Pesticide Contamination

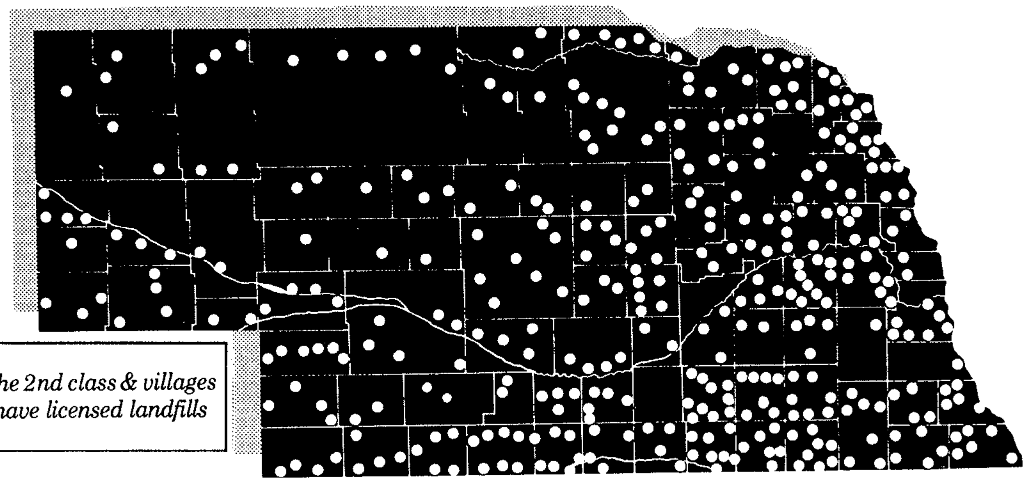
As discussed earlier, pesticides have been detected in nonpoint nitrate-contaminated groundwater in the Central Platte NRD and in Holt County. Because Nebraska has not designated a state agency to accept enforcement responsibility for the 35 products listed as restricted-use pesticides by the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), the regulatory authority for pesticide use in Nebraska remains with the EPA. Nebraska is the only state that has not accepted enforcement responsibility for FIFRA. If the national Groundwater Safety Act and FIFRA amendments become law, the enforcement of this new and more stringent groundwater-protection legislation also will remain with the EPA.

The EPA could ban all pesticide use in Nebraska and, consequently, could shut down agriculture within the state. Although this is very unlikely, the reluctance of Nebraska to assume responsibility for FIFRA will, most likely, precipitate increased regulatory action by the EPA in Nebraska. The absence of a state agency to enforce FIFRA has caused communication problems between Nebraska and the EPA, and it has left Nebraska without a pesticide regulatory agency.

Presently, the use of pesticides deemed environmentally unsafe by university researchers in other states cannot be restricted or banned in Nebraska. Consequently, insecticides, such as aldicarb, that can be leached from soils easily, will, in all likelihood, be applied to potatoes grown in the Sand Hills.

Presently, the use of pesticides deemed environmentally unsafe by university researchers in other states cannot be restricted or banned in Nebraska. Consequently, insecticides, such as aldicarb, that can be leached from soils easily, will, in all likelihood, be applied to potatoes grown in the Sand Hills. Aldicarb, which has already contaminated the groundwater on Long Island and in Florida and Wisconsin, will most likely contaminate the highly vulnerable Sand Hills groundwater. As with nonpoint nitrate contamination, the course of action will be remediation. The wiser position, and one hindsight should have taught us, is prevention. Applications of aldicarb should be banned in the Sand Hills and on other highly permeable soils in Nebraska. Many states, including Massachusetts, California, New York and

359 unlicensed "open dumps" have been documented in Nebraska



Currently, cities of the 2nd class & villages are not required to have licensed landfills

Nebraska Department of Environmental Control -1986-

Florida, have either restricted or banned the use of pesticides that are known to contaminate the groundwater.

In areas of Nebraska where the primary groundwater-producing unit is contaminated, a deeper, secondary producing unit has become the major source of potable water. Regulation of well construction is needed to protect these secondary producing units from contamination introduced by lax drilling practices. Because most center pivots require a minimum of 800 gallons of water per minute to operate, and more if they are to operate efficiently, irrigation well drillers need to provide maximum water yields. In many areas of Nebraska, drillers are obtaining groundwater from more than one producing unit to obtain a high yield well. Layers of fine-textured sediments (aquitards) between aquifers naturally limit the transfer of water between producing units. Screening the well or gravel packing the space between the borehole and casing in the two producing units provides a pathway for chemical exchange between the water-producing units.

Because the lack of site-specific hydrologic data and accurate drilling logs leaves doubts about the groundwater flow pattern in many areas of Nebraska, the application of potentially toxic compounds through chemigation systems should be limited to areas away from high-yield municipal wells.

In a documented case, tracer compounds were injected into an irrigation well 3 miles west of Grand Island. The tracers moved out of the bottom of the well, through a gravel-packed borehole in the aquitard (60 percent clay and 40 percent silt), and into the secondary producing unit. This occurrence is a direct result of drilling the hole deeper than necessary and back-filling with gravel. Many irrigation wells in this area, and presumably in other areas of Nebraska, are drilled through aquitards and the annular space packed with gravel or screened in two or more water-producing units. Pressure differences, caused by pumping from both producing units, usually result in the downward movement of the groundwater; consequently, the holes in the aquitard act as conduits for recharging the secondary producing unit. If the groundwater in the upper producing unit is contaminated, in this case with agrichemicals, the window in the aquitard provides a vehicle for the vertical spread of the pollutant.

Certainly some of the 350 to 400 unlicensed open dumps in Nebraska are receiving hazardous waste that could be contaminating the groundwater.

Unfortunately, pressure differences of a few feet between two producing units are not usually noted by well drillers. While the rules and regulations being written for well construction address drilling through confining layers, these layers would be recognized by drillers only if there were large differences in pressure between the water-producing units. The new rules and regulations will not allow wells to be screened in two producing units if one of the units is known or suspected of having contaminated groundwater. Overdrilling, as observed in the central Platte area, is not addressed in the forthcoming regulations.

Many irrigation wells that are drilled through the aquitard or screened in two or more producing units are used to chemigate. If the backflow-prevention equipment fails, the potentially toxic compounds would be siphoned into the secondary aquifer. Because the lack of site-specific hydrologic data and accurate drilling logs leaves doubts about the groundwater flow pattern in many areas of Nebraska, the application of potentially toxic compounds through chemigation systems should be limited to areas away from high-yield municipal wells. This precaution should be used in addition to the mechanical safety devices already required by the Nebraska Chemigation Act.

Waste Disposal

Although hazardous and low-level radioactive waste disposal are politically unpopular issues, Nebraska should develop secure disposal facilities for both types of wastes. The state would then be assuming rather than shirking responsibility for correctly disposing of the hazardous and low-level radioactive wastes generated in the state. Not only will properly sited facilities with state-of-the-art design for both types of wastes protect groundwater at the disposal sites from contamination, but having accessible sites will protect groundwater throughout the state from indiscriminate disposal of hazardous and low-level radioactive wastes. Certainly some of the 350 to 400 unlicensed open dumps in Nebraska are receiving hazardous waste that could be contaminating the groundwater. In addition to being a potentially lucrative operation, a technologically advanced disposal industry might lure other industries to the state. Properly sited facilities with state-of-the-art design also are needed if the groundwater is to be protected from contamination at solid-waste disposal sites. Alternative waste-disposal strategies should be explored fully. Because of potential groundwater contamination, landfills in Iowa will no longer be licensed after 1990. Iowa presently supports incineration as a viable alternative to landfilling.

Research

While it is evident that there is a need for groundwater-quality protection legislation, not only in Nebraska but nationally, many researchers would say that legislation is now leading technology. Presently, a better understanding of the processes that control contaminant migration in the unsaturated and saturated zones is needed. This knowledge comes from site-specific field studies and not from regional or simulated studies. While local taxing entities, for example NRDs in Nebraska, provide some money for research, the large sums that are necessary for sophisticated equipment must come from the state or federal government. Presently, an inordinate amount of the total funding for groundwater programs is allocated to regulatory agencies and large engineering firms for site investigation and remedial action. Nebraska, with its wealth and dependence on groundwater, certainly should assume a leadership role in groundwater research.

While a successful protection program requires substantial funding, the costs of a preventive policy are much less than those of a corrective policy.

Funding

The appropriation of money for groundwater-quality protection and cleanup lies with the legislature. While a successful protection program requires substantial funding, the costs of a preventive policy are much less than those of a corrective policy.

Several states have used their taxing authority to establish state superfund programs. In Iowa, money raised through fees for registration of pesticides, pesticide dealers and storage tanks; retailers of household hazardous materials; disposal of solid wastes; and taxes on nitrogen fertilizers are directed to a variety of groundwater-protection programs. Iowa also has proposed that $17.5 million in oil overcharge money be allocated to their groundwater-protection fund. Nebraska, on the other hand, lacks a groundwater-protection fund; perhaps it is time to establish a fund to enable research and protective strategies.

Maintenance of Wellhouses, Water-Level Recorders Hardly Automatic

If you don't know what they are, when you come upon them, they look like homemade rockets or weird, cylindrical outhouses: a 3-foot wide by 6-foot high culvert pipe standing on end with a door cut in it, capped either by a cone-shaped or flat roof. But don't be fooled by appearances. They are neither the handiwork of a crackpot inventor nor a way station for an overburdened traveler.

They are wellhouses. And Bob Hansen builds them and installs them, as well as installing and maintaining the water-level monitoring equipment housed inside them. In fact, Hansen, basic-data supervisor for the Conservation and Survey Division, helped design this particular kind of wellhouse.

"I put these metal houses out," he explains. "They're a good deal stronger and not as susceptible to damage as the wooden ones they started with. I guess the (groundwater-level monitoring) program was started originally as a temporary measuring program. Then the irrigation became so heavy, they continued it. And it got to be a very useful tool for the people who make decisions on water."

The wellhouses mark the groundwater-level observation wells and protect the well-monitoring equipment from the ravages of the weather, rodents or vandals. The program was one of the first of its kind when it began as a cooperative venture with the U.S. Geological Survey (USGS) around 1930; besides the two main agencies, it now involves all of Nebraska's Natural Resources Districts, as well as the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, the Central Nebraska Public Power and Irrigation District, groundwater conservation districts in five counties, county extension agents in three counties, the Omaha Metropolitan Utilities District and the Lincoln Water System. All these agencies contribute annual water-level data. Each year, a comprehensive report, "Groundwater Levels in Nebraska," co-authored by a USGS and a CSD water scientist, is issued detailing significant rises and declines in the state's water levels.

And without the automatic, continuous water-level recorders, the cooperative groundwater-level monitoring program would hardly exist. Although some of the readings are taken by hand, it would be prohibitively time-consuming and expensive to get all of the readings from some 3,600 observation wells manually.

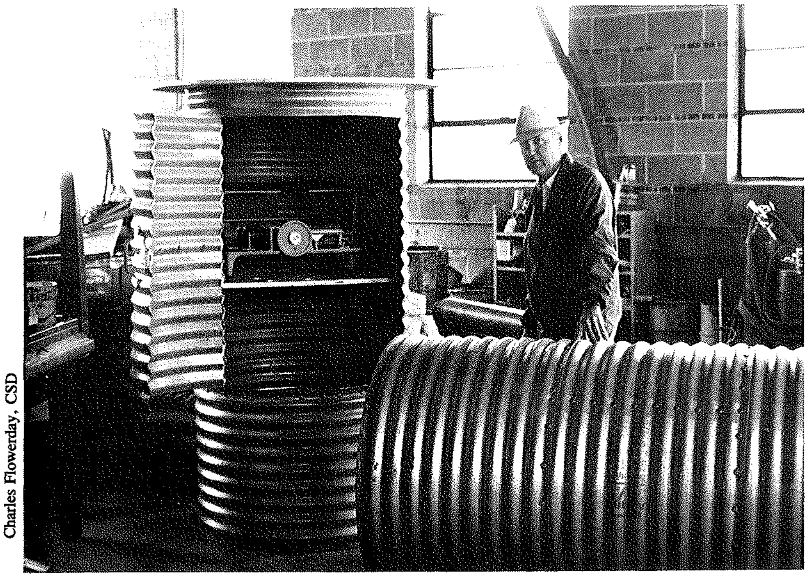
In CSD wells with continuous recorders, a float system detects depths to water, which are then recorded graphically on a chart. The CSD recorders are run by a grandfather-clock type of descending weight that must be drawn up every 30 days, Hansen says. In addition, the clocks and recording machines need periodic cleaning, and paper and ink must be replaced about every 6 months. The machines also must be readjusted if their timing is in error. And occasionally, the clock weight can freeze, stopping the record-keeping cold, he adds.

"These machines probably cost around $2,000 for a new one. I don't know what the life of the machine is. I guess some of them are probably 30-40 years old already, but they're so well-built, they last that long," he says.

"We install the houses, and we install the (recording) machines," Hansen explains. "The machines that I have charge of are basically machines that use graphs. And you can see what the water level is doing from day to day and hour to hour on the graph."

When he's done checking a well station out, Hansen says, he writes the water level on the outside of the wellhouse for people, particularly irrigators, in the area.

"If they need that information, it's readily available. All they have to do is stop at the house and look on the side,



Charles Flowerday, CSD

Bob Hansen, basic-data supervisor for CSD, stands near a section of culvert pipe that will become the next wellhouse he assembles. His latest construction is to his right.

and they can see the records for the last 6 months," he says. "One fellow said that during the irrigation season, probably 40-50 people stop at the wellhouse and check it as they go by."

Landfill Siting 'Got More People Interested in Garbage'

When the City of Lincoln's Public Works Department was faced with siting a new city landfill 2 years ago and hired engineering consultants to choose the location, it could have done so behind closed doors, telling the people of Lincoln and Lancaster County after the fact about the new site. Some of the city's residents even might have preferred that kind of a decision, according to Ann Bleed, a University of Nebraska-Lincoln natural resources engineer who became involved in the siting process as a private citizen. But instead it chose to go to the public, seeking input on the siting process through a landfill-siting committee.

Though fighting the apathy of those not immediately affected by the political, economic or environmental problems associated with waste disposal was a serious concern, Bleed explained, the process did produce a permanent landfill-monitoring committee, a group of citizens charged with being permanently on watch over the landfill, as well as a committee charged with examining possible alternatives. " 'Out-of-sight, out-of-mind' does not exist for these people," she added.

While the decision may not have always pleased the people who made it, Bleed suggested light heartedly, it did produce obvious benefits. First, it resulted in a reasonable choice of a site, she said. And by bringing more people into the process through a broad-based committee, the decision "got more people interested in worrying about garbage," the Conservation and Survey Division researcher said. Consisting of various city and non-urban residents, the landfill-siting committee included, among others, a geologist, an engineer, a teacher, business people, politicians, housewives and someone from the city's park board. Though the debate over a site probably resulted in a larger bill from the consultants, the siting committee allowed for several opportunities for citizens to provide their input, she added.

A Ph. D. ecologist with an M.S. in management systems engineering that included a minor in water resources, Bleed served as vice-chair of the mayor's Landfill Siting Committee and chair of the mayor's Solid Waste Disposal Alternatives Task Force. Currently, she serves on the Landfill Monitoring Committee and the Lincoln-Lancaster County Board of Health.

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" 'Out-of-sight, out-of-mind' does not exist for these people," she added.

Two accomplishments of the alternatives committee were establishing a gate fee—over the initial objections of the city's garbage haulers—and the city's purchase of a wood chipper after a year of lobbying Public Works, Bleed said.

Siting a landfill, however much the public might want to ignore it, is not a decision of little consequence, she explained, as evidenced by cleanup efforts at a landfill in

Minnesota costing $10,000 for every ton of garbage put in. In fact, one positive development coming out of the discussion about the landfill was a more accurate assessment of the true cost of a landfill—which might also include the cost of litigation—compared with various alternatives.

That alternatives were even examined was another positive note of the landfill-siting story, Bleed said. One of the reasons the issue of alternatives arose was that county residents were concerned about having the landfill near their property and began pointing out other possibilities besides burying garbage and began examining their costs.

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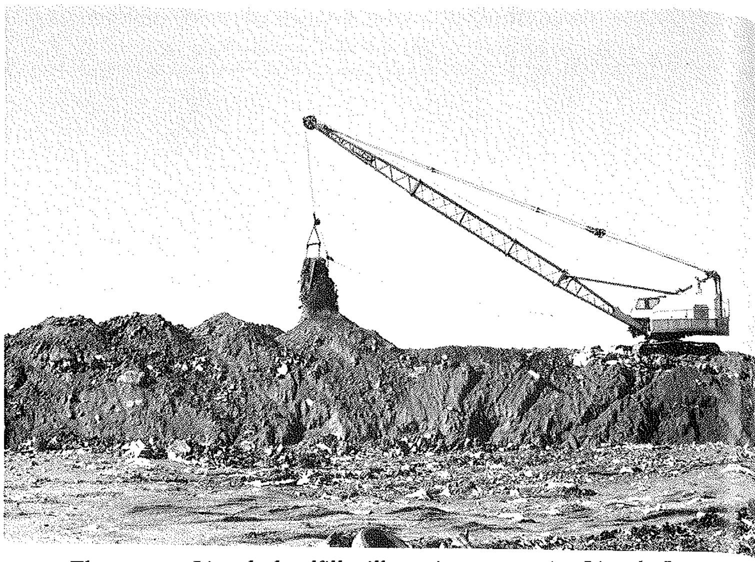
Since the choice of the landfill site, Bleed said, a number of significant developments have demonstrated increasing local and national awareness about other means of disposing of solid waste. Among these are the city's hiring a full-time recycling coordinator, Gene Hanlon; the recommendation of the Solid Waste Disposal Task Force that the city pursue recycling as a means of extending the life of the new landfill; and the recommendation by the mayor's Landfill Operations and Alternatives Task Force that the city begin a full-scale composting program that would include grass clippings, leaves, brush, tree limbs and other biodegradable vegetative matter. This could start with a lawn-waste composting service, Bleed said, because much lawn waste is already bagged and hauled separately by lawn services and individuals. In addition, she noted that the state of Rhode Island has recently begun a state-ordered garbage and household-waste recycling program. Such programs also are mandatory in some cities across the nation, she added.

Simply by keeping material out of the landfill, recycling can extend its life. Savings to the public on the siting and development of a new landfill is enough to pay for the cost of a recycling service, even if the recycled material is given away, she said. Public Works figures show that the start-up costs of the new landfill were about $4 million and that the new site will require about $1.5 million to $2 million a year to operate. Less garbage means the landfill lasts longer; therefore, start-up and operating costs are spread over a longer period, she explained.

Regarding some of the political dimensions of the siting process, Bleed said a polarity developed between city and other county residents regarding siting a new landfill outside the city limits that would probably contain more garbage from within the city limits than from outside them. In addition, other lines of debate were drawn between the consulting engineers and the scientists on the siting committee, as well as between the siting and alternatives committees and Public Works.

In general, residents outside the city limits were concerned about blowing trash, odors, increased traffic, possible contamination of wells and lowered property values. These residents typified the "not-in-my-backyard" syndrome, while the majority of city residents were apathetic as long as the new landfill was cheap, Bleed said.



The current Lincoln landfill will continue to receive Lincoln-Lancaster County waste until the new landfill is ready to go sometime this spring.

Disagreement between the consulting engineers and the siting-committee scientists focused on the engineers' contention that the fine-grained glacial till deposits that mantle most of eastern Nebraska, combined with state-of-the-art engineering, provided adequate safeguards against contaminant leaching, Bleed said. The scientists argued that till isn't the same everywhere—sand lenses may exist—and that no one could guarantee groundwater contamination would not occur unless much more data about the sites were gathered. Even so, any guarantees were practically impossible, the scientists contended.

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In the midst of this kind of disagreement, the Public Works Department and the people living near possible sites were at times confused, she said. Eventually, the sites were ranked for geological settings by a subcommittee of the siting committee made up of engineers and geologists. The siting committee as a whole took this information, as well as considerations such as traffic, noise, odor, etc., and chose a site.

Following the committee's choice of a site, a design committee reviewed the plans for development of the site. Among those on this committee were Sam Treves, chair of the UNL geology department, for whom CSD research geologist Frank Smith filled in near the end of the process, and research chemist Mary Spalding, who chaired the committee, as well landowners from near the new site.

Overall, the process did work and provided those involved with "hands-on" experience in making government responsive to local concerns about environmental issues, Bleed said. Also, the city should be commended for the degree to which it included the public in the decision-making process, she added.

Hazardous Waste Disposal Site Must Meet Geologic and Hydrologic Criteria

Reconnaissance surveys and on-site inspection should be required before selecting or licensing any site for disposal of hazardous waste in Nebraska, said Marv Carlson, University of Nebraska-Lincoln research geologist with the Conservation and Survey Division. This includes any site chosen for disposal of low-level radioactive waste.

Moreover, any site selected should meet a comprehensive list of geologic and hydrologic criteria, explained Carlson. The CSD geologist has been a technical consultant to the Low-Level Radioactive Waste Compact Commission, the five-state compact charged with locating a low-level radioactive waste disposal site in one of the member states. The other states involved are Arkansas, Kansas, Louisiana and Oklahoma. Nebraska was chosen as the host site at a compact commission meeting in December.

In addition, Carlson is part of the group giving technical advice to the state task force appointed by Gov. Kay Orr to help determine the site for disposal of low-level radioactive waste. He also has prepared a manual on the siting of hazardous waste facilities for the Nebraska Department of Environmental Control.

The interrelated natural characteristics of the host environment will control the dispersion and migration of any kind of hazardous waste, Carlson explained.

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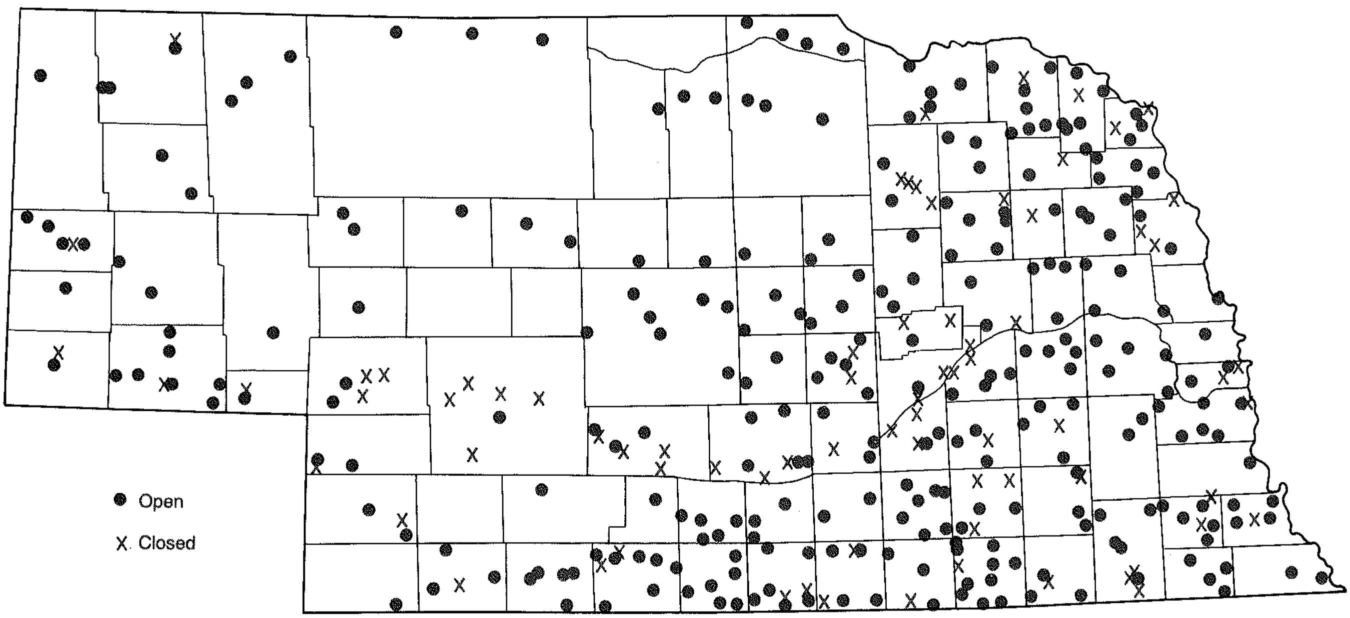


Solid-waste disposal sites

(adapted from "Groundwater Pollution Potential in Nebraska, 1983," a cooperative map project of the Conservation and Survey Division and the Nebraska Department of Environmental Control)

Construction, operation and siting of solid-waste disposal sites—except those operated by cities of second class and villages—are regulated by a state licensing program administered by the Nebraska Department of Environmental Control. Groundwater-quality monitoring, which can assess the movement of fluids related to buried wastes, is required of all licensed landfills.

Prior to state regulation, many landfills and garbage dumps were improperly sited, constructed and operated. Many abandoned and unlicensed landfills are located along streams, where soils typically are highly permeable and the water table is at a shallow depth. Some of these sites are potential sources of numerous inorganic and organic chemical contaminants in underlying groundwater resources. Some landfill wastes contain heavy metals, pesticides or other toxic organic compounds that pose a threat to human health.

The reliability of the inventory data for the solid-waste disposal sites depicted on the map is variable. For closed sites, the data depend at times on incomplete written records and occasionally on personal recollection. For unlicensed operating sites, the data base is also incomplete. Because comprehensive information is compiled for licensed sites, the data base for these sites is excellent.

contact between the waste and the environment. Though the contact will be restricted, if this isn't part of the plan, all that has been accomplished is storage, not disposal.

Some of the desirable natural factors involved in the choice of a site are:

—Low rainfall: since most of the water that comes near or reaches the waste will be infiltrating precipitation, this is particularly important;

—Deep water table: this will help minimize contact with groundwater;

—Modest soil permeability: the choice and design of the site should allow monitoring agencies to control and predict the movement of any leachate. Very low permeability may not provide the best kind of dispersion and chemical interaction;

—Slow-moving groundwater: the site should not be in direct contact with the groundwater, but a flow system that can be monitored is important for dispersing the possible leachate.

—High adsorption and ion-exchange capacity: this pertains to the rate at which chemical interaction and potential disintegration occur within the host environment;

—Topography and soils that minimize erosion: surface disruption during the disposal period and afterward should be avoided;

—Avoidance of land-use conflicts: sites should be "screened out" that conflict with existing human activity, extracting minerals, bodies of surface water and preservation areas;

—Low probability of natural hazards: sites with hazards such as faulting, volcanoes and unstable land should be eliminated.

—Adequate buffer zones: this will help contain the waste and its by-products in case of unforeseen circumstances.

—Homogeneous (consistent) geology and hydrology: the site needs to have predictable characteristics to allow for effective monitoring.

Carlson also explained that a siting process moves through three screening levels that involve examining sites in increasing degrees of detail.

"In the low-level radioactive waste project, we went into a level II phase, and before we could get the contractor shut off, he went to level III, to the extent of appearing, at least to the general public, to have identified specific sites without having done any on-site investigation," Carlson said regarding some of the adverse publicity the siting process has received. "The compact has identified a contractor (U.S. Ecology), who will actually emplace the site. And they are starting on probably what you would consider a more effective level II type screening, identifying candidate areas, and hopefully, getting quickly to on-site examination of a variety of sites."

The screening levels are as follows:

—Level I: identifies or eliminates very broad areas, commonly at scales of 1 inch = 5 miles or more. The criteria have a technical, definable basis found in publications or maps. A published map for Nebraska shows the results of a level I screening for disposal of hazardous waste.

—Level II: usually identifies candidate areas within those areas not eliminated after level I and at scales of about 1 inch = 1 mile. Level II limits the number of potential sites by defining acceptable criteria other than physical data, such as land use, proximity to public water supplies and proximity to the infrastructure that might exclude technically acceptable sites.

—Level III: defines and ranks specific sites with the candidate areas at scales of 1 inch = 2,000 feet or less. Major sources of data would be county soils maps and 7-1/2 minute topographic quadrangles. Published data are important at this stage, but on-site inspection and reconnaissance surveys would probably be required. A matrix evaluation system might be created to determine sites suitable for detailed geotechnical investigation.

And finally, when a site is selected, a detailed technical characterization of the facility must be made under the supervision of the appropriate regulatory agency, Carlson said.

Balancing water quantity, quality and environmental needs

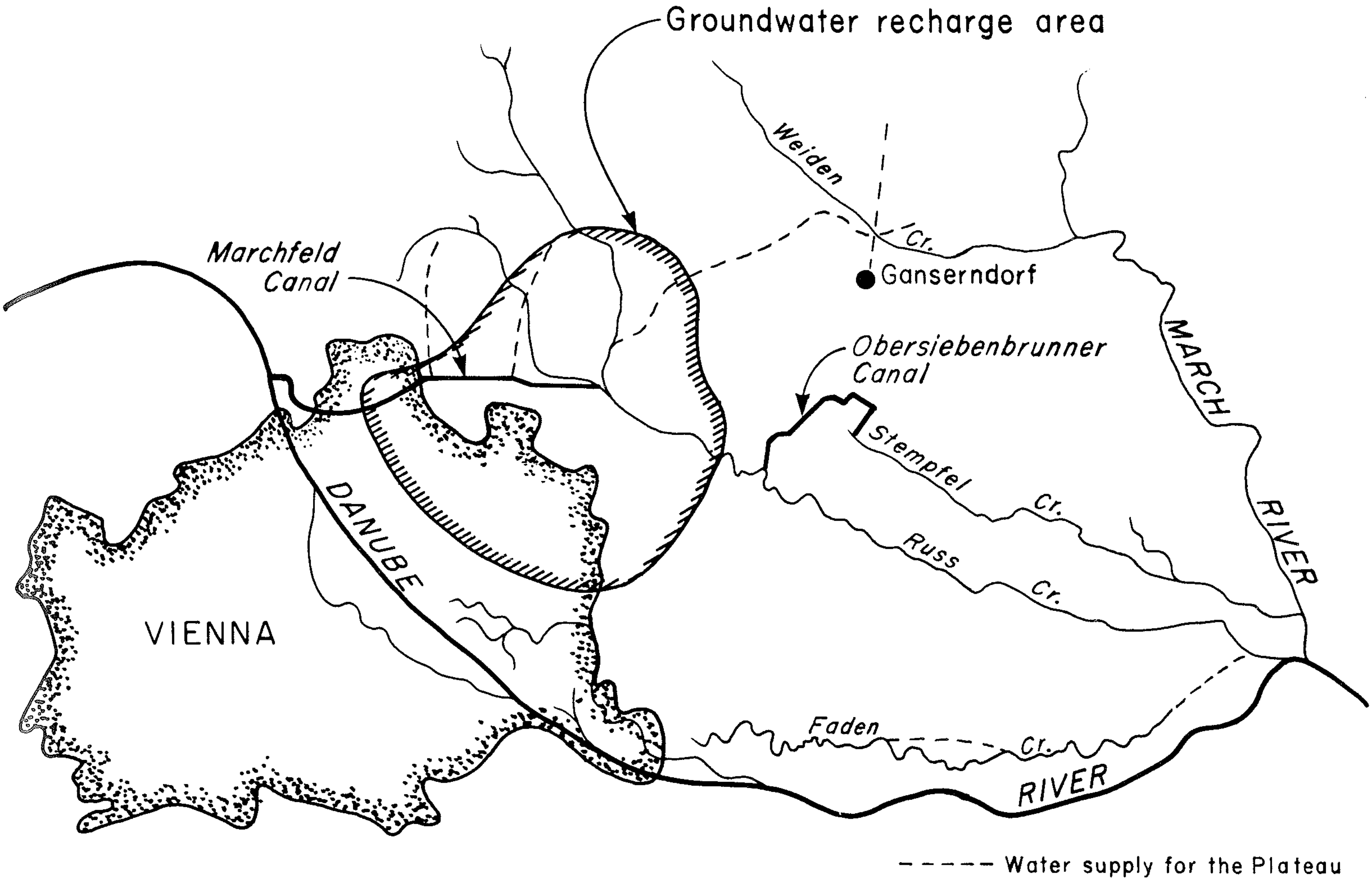
Every Water Decision is Multi-Objective, Says Austrian Hydrologist

by Charles Flowerday
Editor, CSD

Although it received approval from the highest federal water-law authority, a recent Austrian water development project lacked an environmental-impact study and did not involve the general public early enough in the planning process; as a result, it was never built.

In another Austrian water project, policy-makers came closer to realizing that "every water-related decision is a multi-objective one," according to an Austrian hydrologist. They satisfied local objections concerning economic and environmental needs, and its approval from the Austrian Water Law Authority was "a rather successful decision," said Dr. Peter Nachtnebel, associate professor with the Institute for Water Resources Management at the Austrian University of Agriculture. Nachtnebel's areas of expertise are groundwater management and protection; environmental-risk analysis; multi-criterion decision making regarding water resources; and conflicts of economic versus ecological interests over great Austrian rivers.

In connecting the successful implementation of a water project with the breadth and depth of its planning processes, Nachtnebel added that the multi-objective approach requires a given set of alternatives and accepting certain trade-offs among the various objectives. He presented these two case studies this fall as part of the Nebraska Water Resources Center Kremer Lecture, "Groundwater Management: An Austrian Experience." In addition to studies of his own country, Nachtnebel has pursued comparative case studies of multi-criterion decision making regarding water development in the United States with Istvan Bogardi, University of Nebraska-Lincoln visiting professor of civil engineering



The Marchfeld canal

and Lucien Bockstein of the University of Arizona's Engineering Experiment Station.

Although the legal and political considerations differ, sometimes a great deal, both Austrian case studies have parallels to water management in Nebraska. While one case study dealt with water quantity and quality problems in an agricultural area, the other focused on the conflicting need for water for power and for habitat at an important stopover for migratory birds. Those familiar with the development of the state's groundwater and surface water will recognize that many of these issues have confronted Nebraskans as well. In fact, the proposed Prairie Bend water project is a classic example of multi-objective water development, a project designed to recharge an area experiencing water-level declines while also safeguarding habitat for migratory fowl that depend on Platte River flows.

"I think it's always helpful to exchange ideas and learn from another country," Nachtnebel added in a later interview.

The case study of the successful project focused on the appropriate management of a large groundwater regime in a 1,000-square-kilometer basin that is widely irrigated and produces about 10-15 percent of Austria's total agricultural products. Other significant industries in the area are food-processing enterprises that also depend heavily on groundwater.

The area also was experiencing groundwater quantity and quality problems that should be familiar to Nebraskans. Two or three decades of pumping for irrigation had contributed to a lowering of the water table. In addition, recent studies had shown an increase in groundwater pollution, particularly by nitrates, he explained.

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The success with which the development project met a varied list of objectives, Nachtnebel said, was due largely to the following four factors:

—The government created the Austrian Commission for Regional Planning, a special inter-disciplinary, inter-departmental agency—endowed with advisory power only regarding water management—but one that would act as a lead governmental agency.

—Through this agency, the public was included in the early stages of the planning process, so any objections could be considered and negotiations begun.

—Another agency, responsible for implementing the irrigation scheme, produced a voluntary environmental-impact study.

—Though the regional planning commission had no legal authority, by representing many different kinds of expertise and interests, it could examine the objectives necessary to the region, could invite testimony from experts and could comprehensively address the situation, laying the groundwork for an effective planning process.

After many hearings and deliberations, the planning commission recommended:

—Agricultural production in the region be increased and yields in dry years be safeguarded;

—The possibilities for further increases in agricultural production be guaranteed in case of emergencies;

—The water supply be improved for all relevant regional economies;

—Low-flow augmentation of the small streams occur to improve their water quality; they were becoming polluted with organic matter and contained low levels of dissolved oxygen as a result of wastewater from local food-processing industries.

However, because of increasing sensitivity to environmental concerns in Austria, the agency responsible for building the water-transfer system did its own impact study. This resulted in an irrigation canal, the Marchfeld canal, that was not just a concrete channel transferring water only. Instead, simultaneous consideration was given to recreation and wetland needs.

All this would be accomplished by transferring water from the Danube River into that basin, Nachtnebel explained, adding that the impact on the Danube was minimal since the diversion was less than 1 percent of its flow. This diversion would be used to artificially recharge the area's groundwater.

In addition, special attention was given to the environmental effect of the project, he said, also explaining some of the legal aspects of the project. Because groundwater rights are not tied to property rights, as they are in Nebraska, every use of water in his country must be approved by the federal water-law authority, he said. This authority must decide above all whether the development is in the interests of Austria's national economy. If it is, environmental considerations are not as important legally because environmental protection legislation occurs on the provincial (state) level.

Because Austria needed to rebuild its economy quickly after World War II, environmental protection was not as high a priority as using water for economic development, Nachtnebel said. Therefore, even today, no environmental-impact study is required by the federal water-law authority.

However, because of increasing sensitivity to environmental concerns in Austria, the agency responsible for building the water-transfer system did its own impact study. This resulted in an irrigation canal, the Marchfeld canal, that was not just a concrete channel transferring water only. Instead, simultaneous consideration was given to recreation and wetland needs. The project is now being built and should be finished in about 2 to 3 years, he said.

Though Nachtnebel said the public could have been more completely represented in the project's planning, discussions with local farmers about the quality of local surface water led to an investigation of local concerns. As a result, certain technical aspects of the project were replanned to satisfy local objections.

The project represented a typical multi-purpose project, "a real compromise solution," satisfying economic, ecologic and social objectives, he said.

In the other case study, a hydro-power plant to be located on the Danube River downstream of Vienna was never built—even though eight similar projects had been approved using the same kind of justification and even though the federal water-law authority approved the plan.

In this instance, the impoundment of water for hydropower would have seriously lowered the water table under some ecologically unique riparian woods about 40 kilometers downstream from Vienna. Previously, the woods flooded two or three times a year and served as a migratory stopover, a resting and feeding area for many kinds of waterfowl.

Due to the concerns expressed by various ecological experts regarding the fate of the riparian woods, as construction was about to begin, "eco-activists," Nachtnebel said, seized the site and stopped construction.

"Many people supported them, especially in Vienna," he added. Local and national media carried the story of the project and its possible effect on the woods, and it finally became impossible to implement the scheme. As a result of the protests, the federal government established an ecological advisory commission. Composed of experts from the universities and federal and provincial agencies, including the Danube River Survey, the commission recommended that neither the proposed scheme nor any other be built and that, instead, a national park be set up to preserve the environmental particularities of the region, the hydrologist said.

While the federal government decided in May it wants to develop hydro-power projects downstream of Vienna along the Danube, many questions remain open, Nachtnebel explained. To aid in the development of a plan, the government has appointed an ecological advisory board, on which Nachtnebel serves. The board—composed of socio-economic, botany, zoology, climatology, limnology and water-resources groups—will investigate management alternatives that will lessen damage to the environment, as well as ensure economic development. The final compromise might be to build two smaller hydro-power schemes but still divert water into the riparian woods, he said.

"It means we have to think about a new design for such hydro-power schemes," he added.

Mound System an Alternative for Nebraska

Jeff Green
formerly Water Scientist, CSD

Many thousands of Nebraska families rely on septic systems to dispose of household wastes. Properly designed and located in suitable soil, these systems do a good job of treating household wastewater and maintaining the quality of the groundwater. When they are located in unsuitable soil, septic systems can fail and allow wastewater to contaminate the groundwater or surface water. In some areas of unsuitable soil, an alternative septic system, the mound system, can successfully treat household wastewater and protect Nebraska's water supplies.

For a conventional septic system to be effective, several factors must be evaluated to determine a soil's suitability. They are: depth to the seasonal high water table, depth to bedrock and the soil's percolation rate (or permeability). The depth to the high water table or bedrock should be at least 4 feet and the percolation rate should not exceed 60 minutes per inch. In evaluating these factors the following guidelines should be used:

—In areas with a high water table, the wastewater may not be treated adequately before it reaches the water table; the inadequately treated wastewater would then contaminate the groundwater. The same process can occur at sites with fractured bedrock at shallow depths.

—If the soil is slowly permeable (high percolation rate) or if impermeable bedrock occurs at a shallow depth, the wastewater may back-up and "daylight," i.e., appear on the surface of the ground. When untreated or inadequately treated wastewater reaches the groundwater or daylights, a serious health hazard is created.

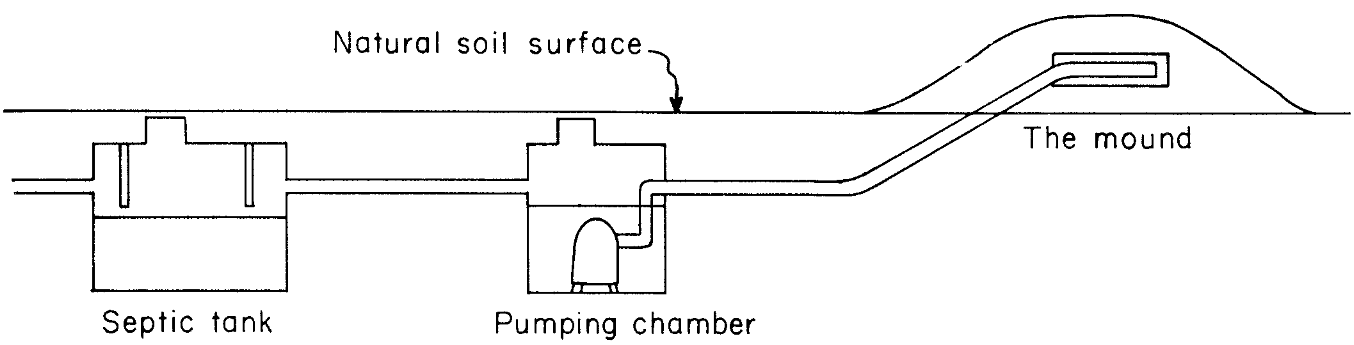
If a site is unsuitable for a conventional septic system, a mound system may be the solution. Basically, the mound system is a subsurface waste-disposal system that is placed above the landscape. The mound itself is composed of clean, medium-to-coarse-grained sand that is covered with topsoil. Inside the mound, the wastewater is pumped out of the distribution pipe into the absorption area. Pumping the wastewater out of the pipe helps to distribute it more evenly. The more even distribution will help keep the sand from clogging in any one area, which should help prolong the life of the system. In areas of slowly permeable soils, the mound system improves the absorption of wastewater into the natural soil. The wastewater is treated as it moves through the mound fill and the natural soil. In areas of permeable soils, the mound system is designed to treat the wastewater before it reaches the water table or bedrock.

Although mound systems can be used on sites that are not suitable for conventional septic systems, there are soils on which a mound system will not function properly. Traditionally, mound systems are suitable for soils that have a percolation rate of about 60 to 120 minutes per inch, or groundwater or bedrock at a depth of about 2 to 4 feet. Generally, mound systems have not been recommended for soils that have a percolation rate greater than 120 minutes per inch or on soils that have groundwater or bedrock at a depth of less than 2 feet.

However, recent research by the University of Wisconsin-Madison's Small-Scale Waste Management Project has shown that mounds can work on sites with very severe conditions for treatment of septic system effluent. Site conditions encountered and overcome were: groundwater at depths of 10 to 12 inches; steep slopes up to 21 percent; and soils that had low to moderately low permeability in the subsoil (as defined by the USDA Soil Conservation Service). They also found that mound systems will work even when they are placed partially over an existing, failed conventional system or when they are placed over fill. Putting mounds on sites such as these, however, requires an extremely high level of technical expertise.

Local regulations that affect the siting of septic systems vary across Nebraska. Before building any type of septic system, the homeowner or builder should contact the local health department or planning agency. Also, additional information on alternative septic systems is available from University of Nebraska-Lincoln agronomist Dave Lewis.

Mound systems are much more complex to design and build than a conventional septic system. Homeowners should not attempt to install a mound system without professional assistance. Properly designed and located, a mound system can satisfactorily treat household wastewater and preserve the quality of Nebraska's water supplies for many years to come.



Cross-sectional diagram of a mound-type septic system

Selected Publications Related to This Issue

Available from CSD

Resource Atlases
—Groundwater Quality of the Central Platte Region, 1974: M. E. Exner and R. F. Spalding (1976) - $5.50 (RA-2)
—Groundwater Quality Atlas of Nebraska: R. A. Engberg and R. F. Spalding (1979) - $3.50 (RA-3)
—The Groundwater Atlas of Nebraska: R. D. Kuzelka and D. T. Pederson, project leaders (1986) - $2.00 (RA-4)

Water Survey Papers
—Effects of Land Use and River Seepage on Groundwater Quality in Hall County, Nebraska: R. F. Spalding (1975) - $1.75 (WSP-38)
—Hydrogeology of Water-Quality Monitoring Transects in an Irrigated Area of the Eastern Sand Hills, Nebraska: D. R. Lawton (1986) - $3.50 (WSP-60)

Water Resources Center Publications
—Strategies for Reducing Pollutants from Irrigated Lands in the Great Plains: M. L. Quinn, ed. (1982) - Free (WRC-1)
—Aspects of Groundwater Quality—Proceedings of the 1985 Water Resources Seminar Series: Nebraska Water Resources Center (1985) - Free (WRC-5)
—Availability of Groundwater Nitrate Data in Nebraska: D. M. Harrell (1986) - Free (WRC-8)

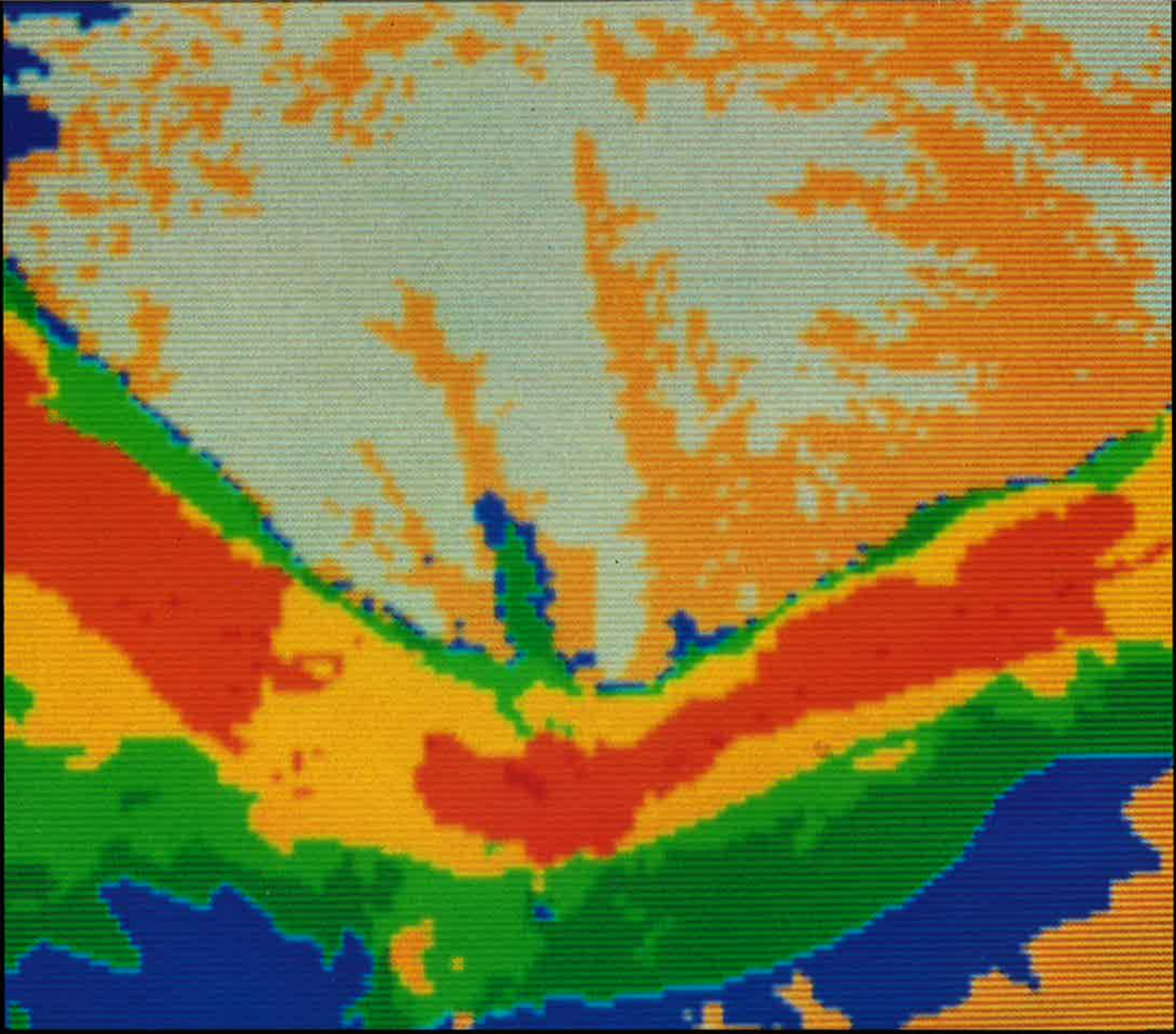
Reprints
—Evolution of Contaminated Groundwater in Holt County, Nebraska: M. E. Exner and R. F. Spalding (1979) - $.50 (RS-25)
—Sources of Concentrations of Nitrate-Nitrogen in Ground Water of the Central Platte Region, Nebraska: J. R. Gormly and R. F. Spalding (1979) - $.50 (RS-26)
—Chemical Seepage From a Tail Water Recovery Pit to Adjacent Ground Water: R. F. Spalding and others (1979) - $.50 (RS-27)
—Water—Pesticides in Ground Water Beneath Irrigated Farmland in Nebraska, August 1978: R. F. Spalding and others (1980) - $.50 (RS-33)
—Groundwater Uranium Concentrations—How High is High?: R. F. Spalding and A. D. Druliner (1981) - $.50 (RS-37)
—Uranium Geochemistry in Groundwater from Tertiary Sediments: R. F. Spalding and others (1985) - $.50 (RS-45)
—Ground-Water Contamination and Well Construction in Southeast Nebraska: M. E. Exner and others (1985) - $.50 (RS-46)
—VOCs (Volatile Organic Compounds) in Ground Water Influenced by Large Scale Withdrawals: A. J. Fischer, E. A. Rowan and R. F. Spalding (1987) - $.50 (RS-65)

Maps
—Groundwater Nitrate-Nitrogen Concentrations, 1980: R. F. Spalding, project director; M. E. Exner, map and text (1:250,000) - $.50 each for Alliance, Broken Bow, Fremont, Grand Island, Lincoln and Scottsbluff quadrangles (GM-48)
—Concentration of Dissolved Solids in the Principal Aquifer in Nebraska, 1980: (1:1,000,000) - $.50 (GM-49)
—Radium-226 Concentrations in Groundwater, Central Platte Region, Nebraska, 1982-1983: R. F. Spalding and C. N. Loope (1:500,000) - $2.00 (GM-58)
—Concentration of Nitrate-Nitrogen in Groundwater, Central Platte Region, Nebraska, 1984: M. E. Exner (1:500,000) - $2.00 (GM-59)
—Center-Pivot Irrigation Systems in Nebraska, 1986: D. C. Rundquist, project leader; J. W. Jones, project researcher (1:1,000,000; 1987) - $.75

Available elsewhere or in press

—A Septic Tank System for Sewage Treatment; NEBGUIDE G79-448
—Maintaining a Septic Tank System; NEBGUIDE G79-446
—Soils, Absorption Fields and Percolation Tests for Home Sewage Treatment; NEBGUIDE G80-514
—Intermediate Vadose Zone Nitrate Beneath Irrigated Cropland: R. F. Spalding and L. A. Kitchen; Ground Water Monitoring Review, in press
—Groundwater Munition Residues and Nitrate Near Grand Island, Nebraska, U.S.A.: R. F. Spalding and R. W. Fulton; Journal of Contaminant Hydrology, in press
—Excursion from Chemigation Backflow: R. F. Spalding and R. E. Cady (1986); *In* Toxic Substances in Agricultural Water Supply and Drainage—Defining the Problems; Proceedings of the 1986 Regional Meetings of the U.S. Committee on Irrigation and Drainage, Denver, CO
—Monitoring Potential Ground Water Contamination in a Proposed Uranium Mining Area: R. F. Spalding and A. W. Struempler (1984); Proceedings of the International Conference on Ground Water Technology, National Water Well Association

In addition, the Cooperative Extension Service has many NEBGUIDES available on nitrates, chemigation and pesticides.



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